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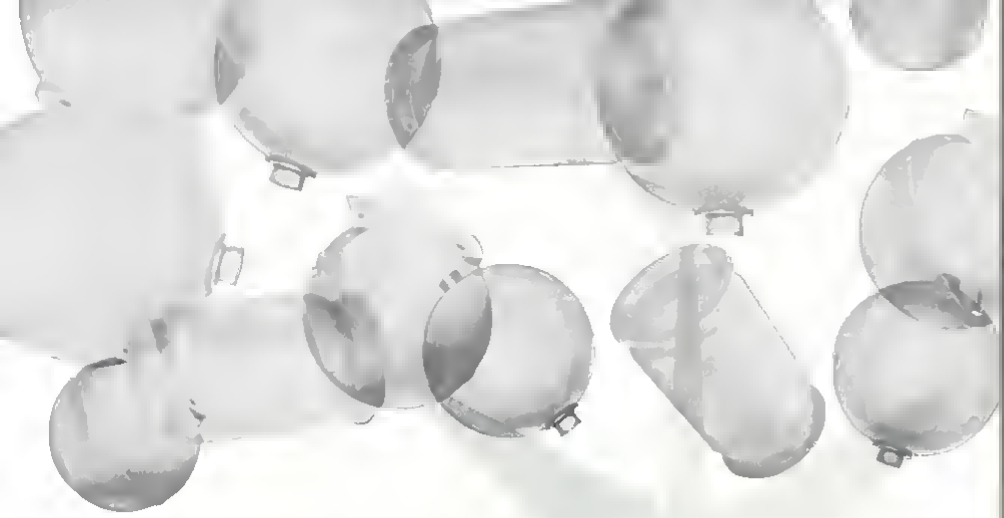
JUNE 16, 1958

Aviation Week

A McGRAW-HILL PUBLICATION

Including Space Technology

Research for Space Edition



PRESSURE VESSEL TECHNOLOGY ...AND NOW TITANIUM

With years of experience in the design and production of airborne pressure vessels such as air, gas and fuel storage bottles for missiles, and tanks for aircraft hydraulic systems, Rheem Aircraft is particularly qualified as a supplier of these components. This specialized technology of welded pressure vessels employing aluminum, steel and stainless steel now dictates the use of heat treated titanium alloys to meet critical strength/weight requirements of the ICBM program. The storage and transport of liquids and gases under extremes of pressure and temperature is now a reality with significant reductions in weight made possible by Rheem sponsored development. Submit your specialized pressure vessel requirements or specifications to the Rheem Marketing Department, Aircraft Division... Rheem's experience is available for your application.

RHEEM MANUFACTURING CO./AIRCRAFT DIVISION

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Rheem

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Circle Number 82 on Reader Service Card→

A simple but precise computer is the brain of Hydro-Aire's famed "Hytrol" anti-skid braking system; a black box that masterminds the braking operation on more than 6,000 airplanes now in use.

This successful production experience—coupled with considerable background in the development and applications of semi-conductors—has led Hydro-Aire into the field of highly reliable electronic system components. Transistorized power supplies, regulators, amplifiers, oscillators—all of advanced design and thoroughly field tested—are now available from Hydro-Aire.

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AVIATION WEEK Including Space Technology

June 16, 1958
Vol 68, No. 24

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Many plants that pride themselves on modern methods are still using *manual labor* for turning and positioning large weldments.

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P&H Welding Positioners can bring modern handling techniques to your weld shop. These laborsaving machines have proved to save as much as 43% of the total welding costs by *mechanizing* weldment handling. A simple push of a button spots the work-piece — no matter how bulky — so that all welds are downhand.

Downhand welding is faster, permits the use of hotter rods, thus speeds production. The work-piece is securely mounted, too, so that the worker's safety is immeasurably greater than when wooden blocking set-ups are used.

Investigate P&H Welding Positioners. Write for "What You Should Know About Welding Positioners," Dept. 312H, Harnischfeger Corp., Milwaukee 46, Wisconsin.

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How to squeeze the last drop of power out of every drop of fuel

Americans in motion depend upon Holley

The startling advances in the last decade in pounds of thrust, in horsepower have exceeded nearly every other decade in America's engine development history. The challenge of contributing to this advance has fallen to Holley engineering teams with such varied problems as lighter weight, more compact fuel controls for jet engines, carburetors with more and more breathing capacity, ignition systems with more and more accuracy.

Holley's two teams of design and manufacturing engineers have developed products as unlike the carburetors of the past as jet engines to Stanley steamers.

Today, Americans stand on the threshold of a decade which will far outmode the power outputs of today. Holley engineers are currently working on control systems for power outputs relegated just yesterday to science fiction.

As in the last fifty years, Americans in motion will depend upon Holley products.

For more information about Holley products, automotive and aircraft, write to HOLLEY CARBURETOR CO., 11955 E. Nine Mile Road, Warren, Michigan.

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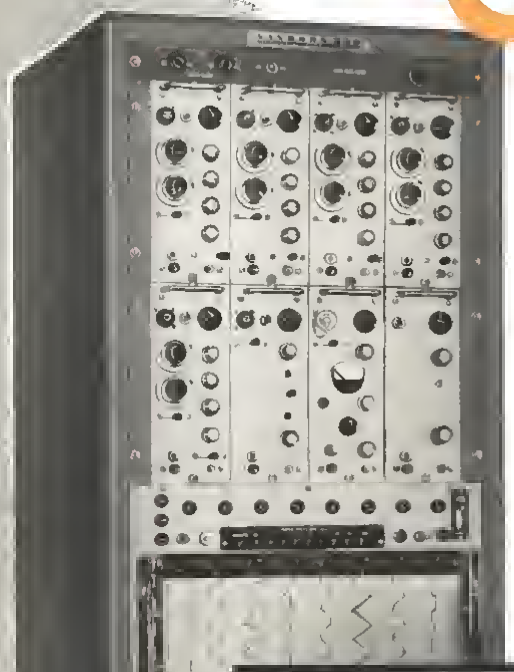
THE NEW SANBORN 350

6- OR 8-CHANNEL OSCILLOGRAPHIC RECORDING SYSTEM



6- OR 8-CHANNEL SYSTEM IN ONE CABINET

Each module of four Preamplifiers takes only 10½" of panel space, complete Recorder-Power Amplifier package only 17½". All controls are on front panel. Total panel space, including ventilating fan and master power panel, 49". Entire system normally installed in one cabinet 22" x 22" x 73¾", to place recorder and controls at convenient height.

FREQUENCY RESPONSE TO 120 CPS

Essentially flat from 0 to 100 cps at 10-division amplitude peak-to-peak, 3 db down at 120 cycles. Built-in pre-emphasis circuit in Power Amplifier.

HEAVY CURRENT FEEDBACK, TRANSISTORIZED POWER AMPLIFIERS

Long term drift less than 0.2 div. over 20°C. changes, short term less than 0.1 div. for 24 volt line voltage changes. Response time 4 ms. In-phase rejection ratio 100:1. Gain stability better than 1% with 20°C. and 20 volt changes.

LINEARITY: 0.2 DIVISION OVER ENTIRE 50 DIV. CHART WIDTH

INTERCHANGEABLE PREAMPLIFIERS WITH INDIVIDUAL POWER SUPPLIES

Compact, plug-in units with 4⅞" x 10½" panels. Present types include Carrier, Servo Monitor (demodulator), DC Coupling, True Differential DC. Can be used separately for driving optical oscillographs, 'scopes, tape recorders, etc.

LIMITER CIRCUIT AHEAD OF POWER AMPLIFIERS ASSURES DAMPING AT ALL TIMES

Limiting of input prevents amplifier saturation or cut off, so that galvanometer damping is never lost.

RUGGED, RELIABLE, LOW VOLTAGE, LOW IMPEDANCE GALVANOMETERS

Fewer turns of heavier wire and completely enclosed coil increase reliability. High torque (250,000 dyne-cm.). Hysteresis level less than 0.1 division. Designed for easy replacement in field.

RECORDER-POWER AMPLIFIER PACKAGE IN ONLY 17½" OF PANEL SPACE

Integral, tube-free package includes eight power amplifiers and power supply, which are power transistors and solid state rectifiers. Operates on 115 volts, 60 cycles. Simple paper loading from front. Individual stylus heat control; chart speed pushbuttons; meter switch; timer-marker switch; fuses; paper footage indicator all on front panel. Connectors for input signals, output monitoring (±1 volt with respect to ground from 2.5 ohm source) and complete remote control provided at rear.

VELOCITY FEEDBACK DAMPING

True damping by velocity signal from separate winding over galvanometer driving coil. Damping control accessible from front of Recorder for easy adjustment.

(ALL DATA SUBJECT TO CHANGE WITHOUT NOTICE)

GALVANOMETER NATURAL FREQUENCY 55 CPS

Higher natural frequency provides higher over-all system frequency response.

INKLESS RECORDINGS IN TRUE RECTANGULAR COORDINATES

Heated stylus creates sharp, smudge-proof trace on plastic coated Permapaper. Chart channel width 1⅞" (approx. 4 cm), ruled in 50 div. of ½" each.

RECORDER-AMPLIFIER UNIT HAS 0.1 VOLT/CHART DIV. SENSITIVITY

Can be used alone, when preamplification is not needed. (Three complete 8-channel Recorder-amplifier-power supply units can be mounted in one cabinet.)

ELECTRICAL PUSHBUTTON CHART SPEED CONTROL, WITH PROVISION FOR REMOTE CONTROL

Any of nine speeds (0.25, 0.5, 1.0, 2.5, 5, 10, 25, 50, 100 mm/sec.) instantly selectable by pushbutton. Plastic strip for channel identification markings.

QUALITY COMPONENTS USED THROUGHOUT

JAN components used wherever practicable, for example, note in the photos hermetically sealed MIL-T-27 power transformers, MIL-approved electrolytic condensers in all power supplies, rugged-ized premium-type tubes in Preamp power supplies, etc.

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INDUSTRIAL DIVISION
176 WYMAN STREET, WALTHAM 54, MASS.

This is the new Sanborn "350" — today's most comprehensive answer to *combined* improved performance, versatility and reliability in an oscillographic recording system of compact size. First *compare* all the "350" design and performance improvements . . . then consider *the many ways they can help you do more kinds* of measurement and recording, with *more* accuracy, speed, convenience and reliability.

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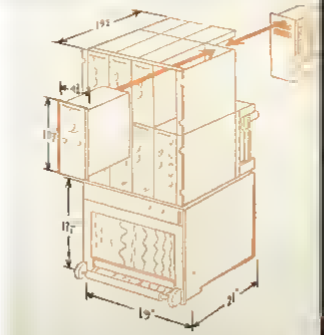

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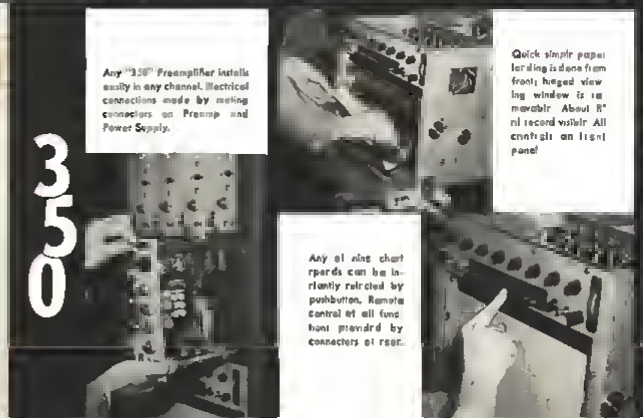
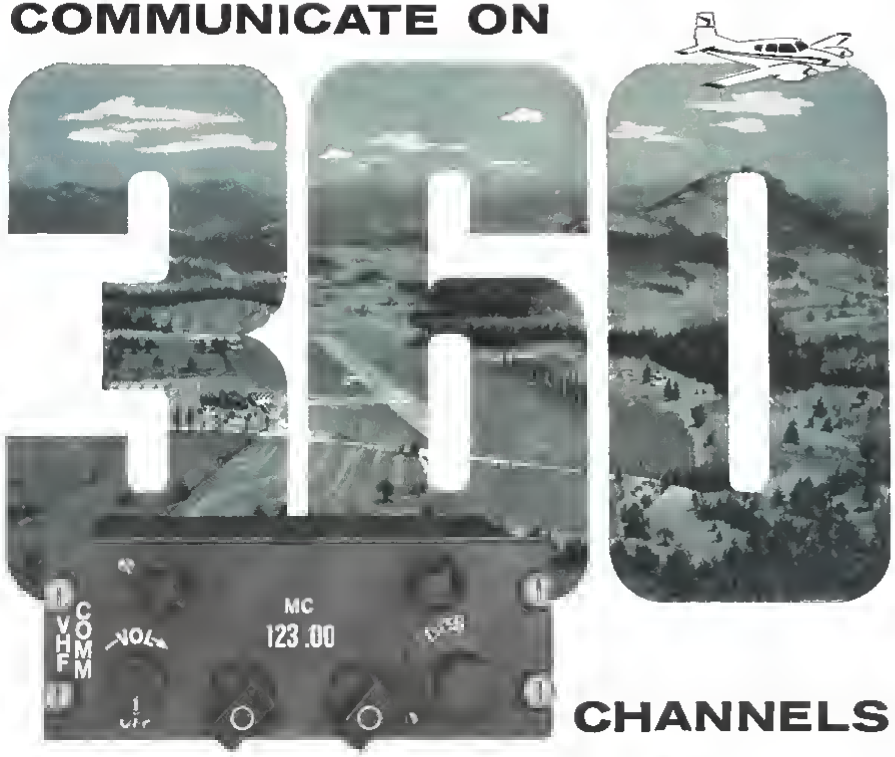


COMMUNICATE ON 360 CHANNELS



WITH ARC's TYPE 210 TRANSCEIVER

The rapidly increasing volume of air traffic and the need for more precise traffic control has necessitated a tremendous increase in the number of assigned radio frequencies to carry on the necessary air-ground communications.

Only a few years ago pilots could operate with 10 or 20 channels. Later frequencies were increased to 80 or 90. Plans now call for 360 frequencies—enough to meet the need for years to come. In view of this channel increase, ARC now offers an all-channel, flight proven transmitter-receiver (Type 210 Transceiver) covering all 360 channels. The powerful 15 watts guarantees optimum distance range and the knifelike selectivity assures freedom from adjacent channel interference. Provision has been made for the selective use of single or double channel simplex whereby transmissions are made on a frequency 6 megacycles higher than the receiver frequency. There is no wait between receiving and transmitting for re-channeling.

This is ARC's latest contribution to air safety. Ask your dealer for a quotation to include a single or dual installation, along with other units of ARC equipment listed below.

Dependable Airborne Electronic Equipment Since 1928

Aircraft Radio Corporation BOONTON, N. J.

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From the whistle of wing struts in the wind to the roar and whoosh of swirling exhaust gasses against a launching pad, Ex-Cell-O has played an important role in aircraft development—working and growing with the aircraft industry as a pioneer in the production of precision parts and assemblies.

From the Ex-Cell-O components logging hour after hour in reciprocating aircraft engines to our precision-made jet rotors and blades, actuators, fuel nozzles, valves and controls, Ex-Cell-O aircraft parts have paid big dividends in superior performance. If you have a problem in precision control or complex flight components which our experience can solve . . . contact Ex-Cell-O today.

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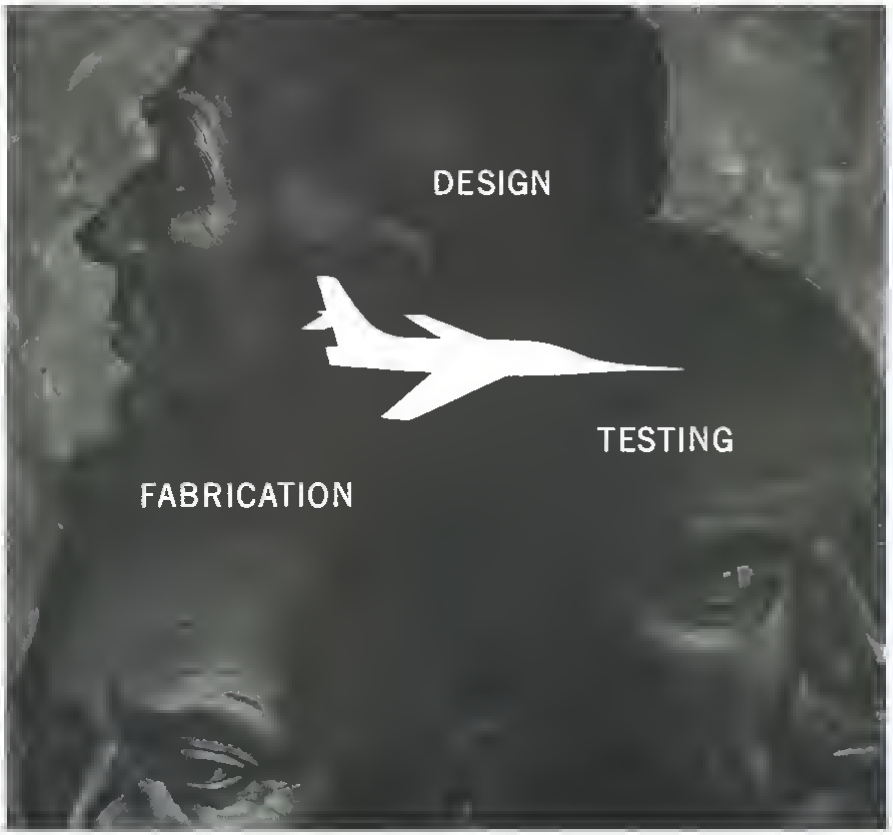
MAN AND MISSILES FLY HIGHER, FASTER AND SAFER WITH PARTS AND ASSEMBLIES BY EX CELL-O



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Built to hold their precision indefinitely, these aircraft bearings are recommended wherever superior quality and high speed operation are required. For some applications, a special alloy steel—developed jointly by Bower and several aircraft companies—is used.

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POWERFUL • SMALL • COMPACT
RELIABLE • LIGHTWEIGHT
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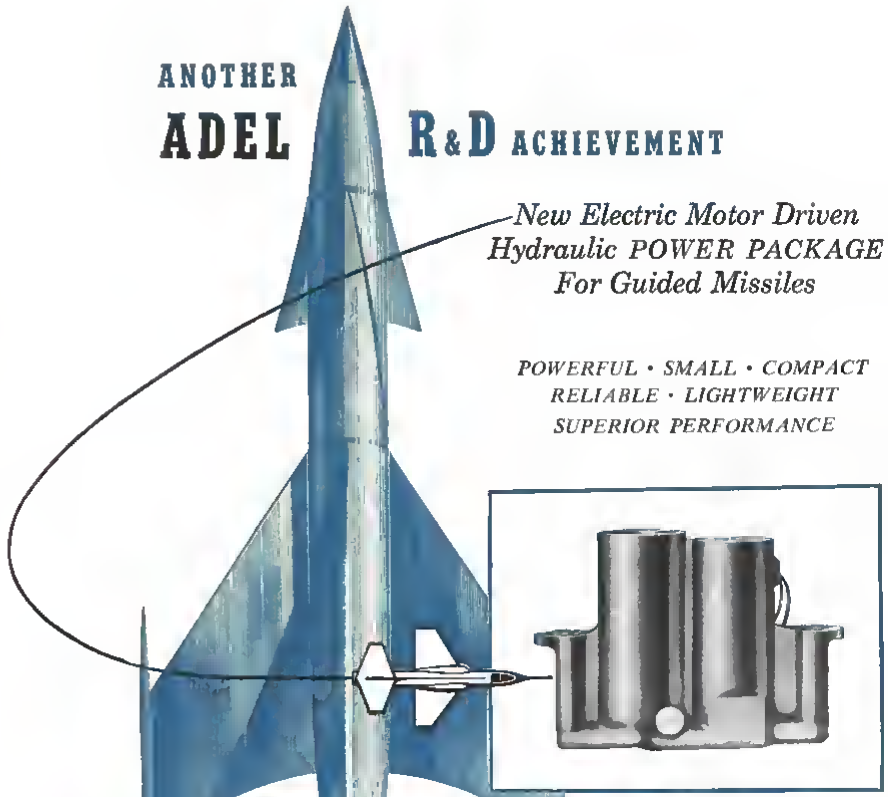

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Other features—high-altitude performance

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with easy handling.

USAF saves training time,

money!

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DOUBLE-ACTING "B" SERIES

PIP® SELF-LOCKING QUICK-RELEASE PINS

the pin that's designed for positive release...even under "over-load" or "bound" conditions!

Double-acting PIP Pins combine rugged strength and dependability with INSTANT INSERTION, SELF-SAFETYING... and QUICK RELEASE! Cotter pins, nuts, bolts and other retaining devices are completely eliminated. Result—unlimited design freedom and accessibility where units are frequently assembled and disassembled... permits quick-change of mechanical units... speeds assembly of portable equipment... reduces servicing costs.

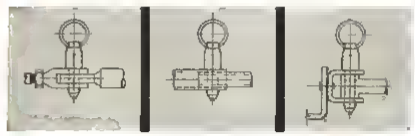
Difficult fastening applications where ordinary fastening devices may "bind" in misaligned holes or under unusually heavy loads are "made to order" situations for double-acting "B" Series PIP Pins, which operate on the fast push-to-insert—pull-to-remove principle... but have the added advantage of the exclusive PIP "drive-in"—"drive-out" spindle. It's the safest, most reliable self-locking quick-release pin available!

MEETS RIGID REQUIREMENTS

Double-acting PIP Pins are used by every major aircraft manufacturer and the military services... are specified for use in missiles... used by leading manufacturers of electronics, industrial and materials handling equipment and have proven their complete reliability in many other fields.

Get exclusive PIP Pin "drive-in"—drive-out" advantages in standard diameters to fit most nominal holes. "B" Series PIP Pins with continuous steel ring aid forcible release and adapts to remote release systems.

Use the experience and technical knowledge of our Engineering Staff to determine the right solution to your quick-release fastening problem.



Clevis fitting Tube assembly Bracket assembly

Technical data and specifications are detailed in Brochure No. ADI-5500. Write for your FREE copy today!

AVIATION DEVELOPMENTS INC.
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He Found Success in the Air

At California's Ontario International Airport, 35 miles from downtown Los Angeles, Shell dealer Les Farrar runs one of the fastest growing aviation service companies in America

As Les will tell you, to run a successful aviation service you must have top-flight products and equipment.

In his own words, "I was looking for an Oil Company that guaranteed quality products—quality service—down-the-line dependability. And I wanted the best dealer-supplier relationship available. I found Shell's approach similar to mine—a 24-hour readiness to go beyond the letter of a contract to be helpful."

So Les Farrar teamed up with Shell 5 years ago.

Today Ontario International Airport provides rapid, efficient fueling service for commercial, military, business and private aircraft . . . in fact just about anything that flies. Growth has been rapid . . . gallonage haa increased *twenty* times in the five years Les has been with Shell.

How does he do it? Les picks up valuable merchandising tips from the Shell dealer magazine. And through the Shell Aviation Specialist, Les keeps posted on new ways to build the kind of service fliers want.

A key part of his service program is the Shell Credit Card System . . . a time-saver designed to help fliers meet exacting schedules.

Business is good at Ontario. In fact it is so good that Les is looking forward to expanding his facilities Plans include a new 2,000-foot runway extension to accommodate the ever-increasing traffic.

The fine reputation of the Les Farrar Aviation Service is widespread and still growing. As for the future? Les himself will tell you that with Shell helping him in every venture—the sky's the limit!

Round-the-clock tower and modern all weather equipment serve the airlines, a Forestry Service fire-fighting unit, an Air National Guard unit and turn-around customers

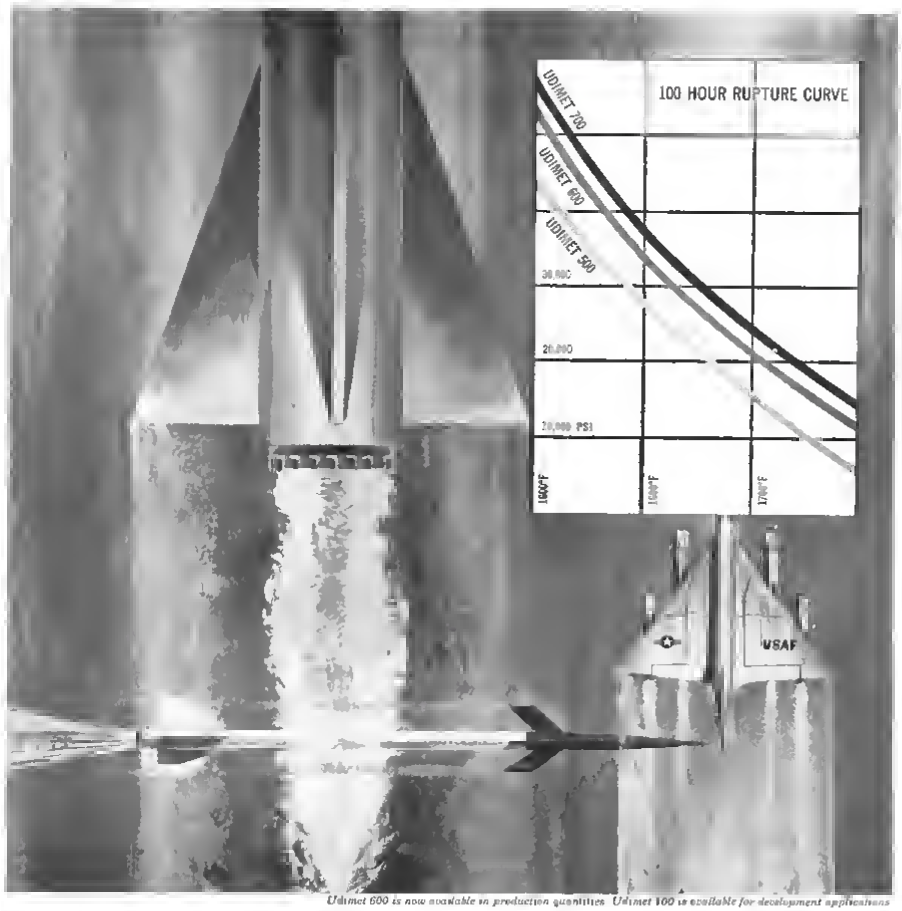
Studying airport expansion plans (left to right) are Art Clark, vice-president of Les Farrar Aviation Services, Thomas E Flaherty, Airport Manager, Fred Stewart, Shell Aviation Representative, and Les Farrar.

Giant military transports come to Ontario for modification by Southern California Aircraft Corporation and Lockheed Aircraft Service Corporation. They rely on Les Farrar for fine service and Shell for high-quality fuels and lubricants.

It pays to be a Shell Aviation Dealer

—and your nearest Shell Office will be glad to tell you why

SHELL



Udimet 600 is now available in production quantities. Udimet 700 is available for development applications.

announcing Udimet 600 and 700

for a wider range of applications at elevated temperatures!

The Utica Metals Division of Kelsey-Hayes scores another materials "break through" with vacuum induction melting. Producible only by the vacuum induction melting process, Udimet 600 and 700 surpass the elevated temperature properties of any other known alloy which can be produced in quantity for critical high-temperature, high-stress requirements. They not only possess excellent stress-rupture qualities but also exhibit high tensile strength at temperatures above 1500°F. Kelsey-Hayes Company, General offices: Detroit 32, Michigan.

U-DI-MET® ALLOYS

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Many vacuum induction melted metals and alloys can now be produced in heat sizes up to 5,000 lbs. by Utica Metals Division.

Some alloys covered by U.S. Patent #2809110

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Automotive, Aviation and Agricultural Parts • Hand Tools for Industry and Home

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CONTOUR TRENTWELD TUBING is available in a wide range of grades including Hastelloy,* Zirconium, Zircaloy, Titanium, 19-9 DL — and in 10 basic tubing classifications (pressure, mechanical, aircraft, heat resistant, ornamental, sanitary, beverage, large diameter, shaping and formed tubing).

*Trademark of Haynes Stellite Co.

get high strength and uniformity with **TRENTWELD** stainless and high alloy pipe and tubing (*sizes range from 1/8" to 40" O.D.*)

As Trent makes them, today's welded pipe and tubing are as strong as — and even more uniform than — pipe and tubing made by any other method of manufacture. That's because (1) an exclusive welding process (Contour Trentweld®) virtually eliminates any bead or undercut, and (2) cold working and annealing after welding make the weld equal in strength and corrosion resistance to the parent metal.

Furthermore, Trent checks the quality of its pipe and tubing with a series of strict tests. All strip going into the welder is checked for width and tolerance. Samples of each lot are tensile tested. Periodic tests — flattening, reverse bend, flare and flange, coil and pressure — are conducted. Pipe and tubing for corrosive applications get rigid corrosion tests. And, if necessary, "single-wall" X-ray inspections, exclusive with Trent, can be made on any lot.

Naturally, pipe and tubing made to these standards can't be surpassed for strength, uniformity and service. But get complete details —

Mail coupon for free 48-page Trent Tubing Handbook — contains complete data on physical, chemical, electrical properties, corrosive data, theoretical weights, hardnesses, etc.

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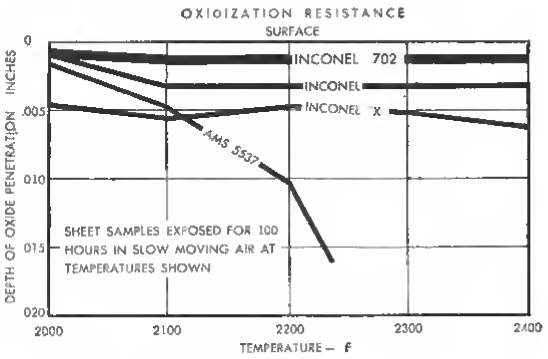


New alloy! New oxidation resistance!

Graph shows 100-hour oxidation resistance that Inconel "702" provides from 2000°F to 2400°F

Inconel "702"* nickel-chromium alloy has been developed for high temperature problems encountered in missile hardware and similar applications

Basically it's a modification of Inconel* nickel-chromium alloy with high-aluminum (2.75—3.75%), low-titanium (0.25—1.0%).

Inconel "702" quickly acquires a thin (±.001-inch) protective coating in high temperature environments. Even up to 2400°F no further penetration occurs, thanks in part to the presence of an $NiAl_3$ constituent.

Inconel "702" can be forged, machined, welded and annealed. Mechanical properties can be improved by age hardening.

Availability

Inconel "702" alloy is available as cold rolled, annealed sheet. Cold drawn wire and tubing and cold rolled strip have been produced in limited quantities, too. For information on these mill forms and others, write to

*Registered trademark

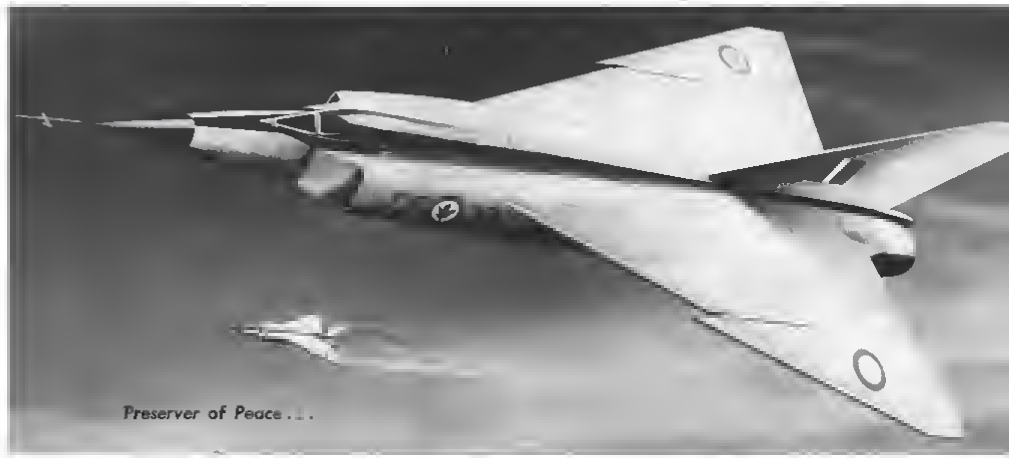
THE INTERNATIONAL NICKEL COMPANY

67 Wall Street — New York 5, N. Y.

INCO NICKEL ALLOYS

NICKEL ALLOYS PERFORM BETTER LONGER

AVRO ARROW



CANADA'S SWIFT, FAR-RANGING ANSWER TO ANY SECURITY THREAT

Every advance in aircraft engineering is exemplified in the Avro Arrow, capable of traveling at well over twice the speed of sound to intercept and destroy enemy aircraft at extremely high altitudes. RCA has been assigned full responsibility for the development of a complete electronic system for fire control, navigation and communication, and an integrated automatic flight control system. While an enemy plane is still beyond the range of human eye, this radar system will detect it, and provide the intercepting pilot with a continuous flow of information, electronically computed in terms of position, range and rate of closing. Associated with RCA in the project are the Minneapolis-Honeywell Regulator Company and several Canadian firms.

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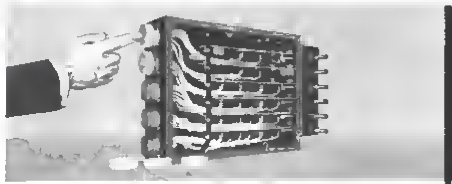
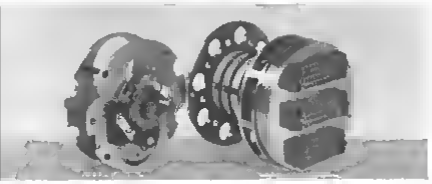
ELECTRO-MECHANICAL CONTROLS, SWITCHES and OTHER COMPONENTS FOR MISSILE-TYPE APPLICATIONS

ELECTRO SNAP has formed MCG . . . .

• "MCG" specialists combine basic Electro-Snap products with others to produce systems of high reliability and precision. This service is made available for aircraft and missile applications alike. It is faster and at lower cost than you can achieve yourself. Typical examples of recent developments are:



Emergency Fire Control—Used in the Flight Engineer's console of the Douglas Globemaster, plunger actuation allows instant emergency operation of any or several of the following: prop feathering, closing cowl and oil cooler doors, stop fuel and electrical service, fire extinguishing system actuation. Unit illustrated handles six distinct areas with instant cancellation of command feature for error correction.

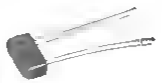


Ground Power Changeover Control—This assembly (airborne) provides remote control of the transfer from external to internal hydraulic power. Of compact and efficient design, its multiple-contact circuit breaking design allows more than 2 amp and 500 VDC capacity with ample margin. Partial assembly only, shown.

Complete Control Panels—Illuminated and instrumented control consolettes are representative of the versatility offered by the new Electro-Snap Modulume panel technique. Lighted pipelines, valve and tank level indications, discrete 'go, no-go' readout areas and illuminated switching controls combined with translucent panels show a new direction in control and monitoring consoles. The basic presentation is the concept of readouts sequencing in changing colors to conserve vital space. Lamp modules are replaceable in ten seconds from front of panel. Front panel configurations are unlimited.

Field-Sensing Control

This switch indicates the presence of an external field of singular polarity—closing one circuit in the presence of a South polarity field and another circuit in the presence of a North polarity field. Operation is at zero to 70 cps and for 500 hours.



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Just ask for "MCG"

MISSILE COMPONENTS GROUP

Men who specialize in aircraft and missile control problems and products

"MCG" is composed of highly-trained technical specialists who fully appreciate and completely understand *reliability* and what it means to you. Their service is available to you for . . .

- **problem analysis through design development, testing and production techniques of *new* electro-mechanical controls, switches and other components for aircraft and missiles.**
- **certified application data and modifications on *existing* control, switches, and other components or assemblies to meet required conditions.**

Regardless of the complexity of your control problems, "MCG" will give you dependable results that can save you time and money.

"MCG" is a unique combination of — new personnel who have been recently very active in the application of components in critical aircraft and missile systems — and long-term employees with profound basic ability and practical knowledge of electro-mechanical devices. Both are particularly valuable in helping you.

HERE'S HOW "MCG" WORKS FOR YOU . . .

"MCG" determines that each —
design
material
fabricated part
part application
and complete assembly

rigidly meets specified environmental and physical requirements according to your needs.

Use this new service on your toughest application problem *now*. Just ask for "MCG", by telephone, wire or letter.

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4232 West Lake Street, Chicago 24, Illinois
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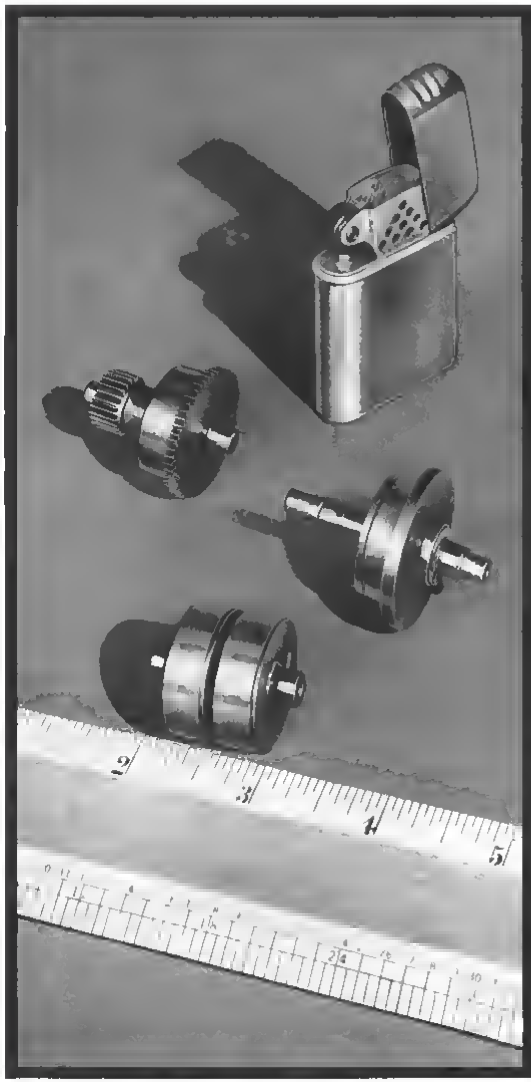

How Much Torque Capacity Can Be Handled In An Inch?

The largest Formsprag clutch shown at left measures less than two inches—weighs about the same as your cigaret lighter—yet delivers more torque per cubic inch than any other available today.

Good news for aircraft, missile and rocket engineers whose job it is to pack more and more power into less and less space. For example, here's how two aircraft component manufacturers have taken advantage of Formsprag's unique clutch design . . .

A landing gear manufacturer has employed Formsprag clutches to over-run the primary hydraulic system so that in case of emergency the pilot can actuate the landing gear mechanically.

An accessory gas turbine manufacturer uses a Formsprag clutch as a disengaging device on a starting mechanism.

If you would like to know more about how Formsprag clutches may be of help in solving your design problems, why not have a talk with a Formsprag engineering consultant?

SEND FOR LITERATURE . . .

ask for new paper entitled "Design Considerations for High Speed Over-Running Clutches."

Over-Running, Indexing and Backstopping Clutches for aircraft, automotive and various industrial applications.

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World's largest exclusive manufacturer of over-running clutches. 58-G

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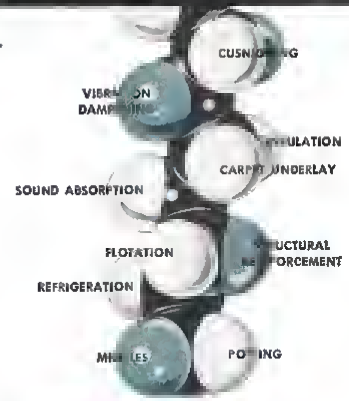
Announces

the opening of the new Freedlander Research and Development Laboratory

The newly-dedicated $1,000,000 plus 25,000 sq. foot Freedlander Research & Development Laboratory

devoted exclusively to the unlimited applications of **STAFOAM**

Rigid, Semi-Rigid and Flexible Polyurethane



Modern industry's need for advanced materials is fulfilled by scientists at Freedlander Laboratory who are pioneering countless formulations and unlimited applications of new miracle STAFOAM.

STAFOAM, a unique type of plastic, offers an unequaled combination of properties and characteristics for industrial design, such as foaming-in-place, adhesion, strength, thermal insulation, energy absorption, resistance to chemicals and solvents, water impermeability, flame resistance, and wide temperature service.

CREATING NEW PRODUCTS

Our research staff is constantly creating and developing new characteristics in existing STAFOAM formulas. The answer to your problem may be immediately available . . . or may require the creative engineering necessary to achieve a specific product. Whatever the nature of your problem . . . *INQUIRE NOW!* Your investigation may uncover an entirely new dimension in the practical use of foamed plastics.

Revealing brochures and technical data on new miracle STAFOAM *will be mailed upon request.*

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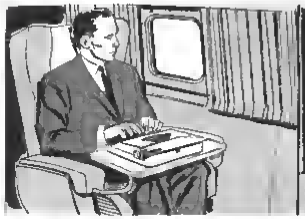
SIESTA SLEEPER SEATS!



Seat in upright position allows you to dine or catch up on your work.

Seat half-reclined, leg rest extended, is perfect for reading or just resting

Seat in full recline provides stretch out comfort for cat naps or sleep

Available at no extra cost on all *TWA JETSTREAM* flights in the U.S.

Here's the most luxurious service coast to coast — and only TWA offers it! Giant TWA Siesta Sleeper Seats at regular First Class fare aboard the magnificent TWA Jetstream. You lie far back for sleep — with six feet, five inches to stretch out in. Or sit up in spacious, living-room comfort to enjoy superb Jetstream Ambassador service. Cocktails and hors d'oeuvres. Wonderful meals *cooked to your order in flight* — freshly brewed coffee, imported liqueurs! For reservations, call your travel agent or nearest TWA office today.

* *Jetstream is a service mark owned exclusively by TWA*

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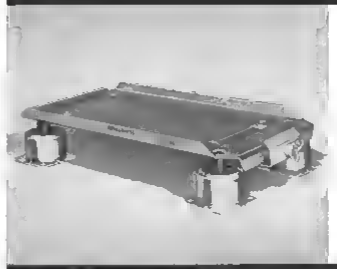
LORD electronic mounting systems

LORD designs and manufactures *complete*, assembled mounting systems in a wide range of standard and special designs. These provide excellent vibration and shock protection for airborne electronic equipment.

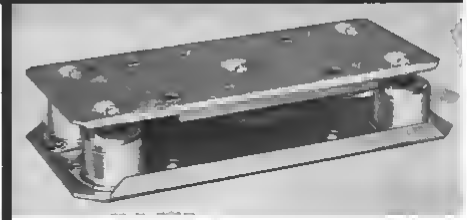
With recently expanded facilities, LORD offers outstanding service on all types of standard bases to meet all pertinent MIL specifications.

Extensive experience can be applied to the design of specialized systems to meet high-performance requirements or to withstand environmental extremes such as high temperatures, high frequencies, steady-state accelerations and transient shock conditions.

All materials and designs are selected to satisfy both performance and economical considerations. To initiate your mounting system project or obtain more information, contact your nearest LORD Field Engineer or the Home Office, Erie, Pa.

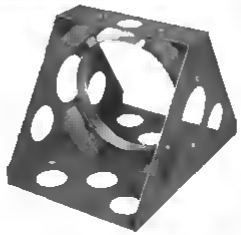


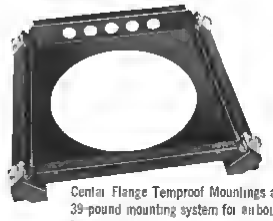
MS 91404-S1 mounting base assembly incorporates Temproof Mountings.



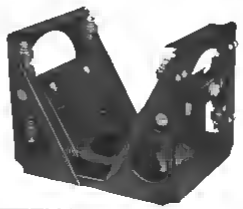
MT 1555/U base with miniature Temproof Mountings provides all-altitude protection for electronic unit

Special all-attitude base with BTR (Broad Temperature Range) Mountings for gyro in jet-powered aircraft.



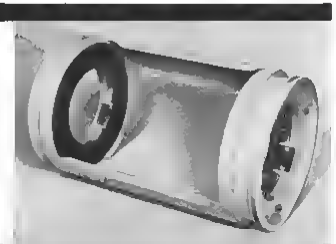


Center Flange Temproof Mountings are used in 39-pound mounting system for airborne antenna harmonizer.



Custom-designed rectilinear mounting system protects missile gyro against rotation from translational inputs.

High-performance mounting system for missile protects canister type electronic units of modular design



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NAA is at work in the fields of the future

Dress rehearsal for survival

Freedom's defense has reached a new frontier—Outer Space. That is why we need new weapons—missiles and men in missile-like planes.

Already America's giant missiles hurtle into space—exploring the new frontier, guarding its ramparts.

And hand-in-glove with missiles are our new manned weapon systems. Compressing years of progress into months, America's military and civilian engineers are jointly pushing our new defenses to completion.

Americans in Outer Space

Today a few chosen pilots are preparing themselves. Donning the new space suits, they sit in altitude chambers, or whirling centrifuges, testing man's reactions to a savage new environment. Their plane, the rocket-powered X-15, is being readied.

The X-15's mission is to take a man into space . . . and to return him to deliver his report. The secrets he brings back will be shared by the Air Force, Navy, and National Advisory Committee for Aeronautics, joint sponsors of the project.

The sinews of space flight

The X-15 is the outgrowth of new technologies developed by North American and its divisions—in guided missiles and supersonic aircraft—in automatic controls and rocket engines. Each is a vital root of the new space flight technology.

NAA's Rocketdyne Division makes rocket engines for the Air Force's Atlas and Thor missiles, and for the Army's Jupiter and Redstone. In fact, every major missile successfully launched in America in 1957 was powered by a Rocketdyne engine.

The Autonetics Division creates automatic control systems for both aircraft and missiles. Only yesterday these tiny fail-proof "brains" were rare technological triumphs. Yet today Autonetics makes them in quantity—with complete reliability.

Weapons—manned or unmanned

Like the Armed Services, North American believes both manned and unmanned weapon systems have their place. NAA's Missile Development Division, backed by 10 years' pioneering missile research, is at work on the GAM-77 advanced air-to-ground missile for the Air Force B-52.

At the Los Angeles Division are two manned weapon systems. The 110A will reach any place on earth at 2200 mph and return to strike another day. The F-108 interceptor's very-long-range radar and atomic missiles will make it lethal to manned bombers and some missiles. It will be a flexible weapon, able to strike at trouble where it starts, before it spreads.

From defense, the arts of peace

North American has not confined its efforts to defense alone. During the past decade it has made great forward strides for the good of all men. The Peaceful Atom, for example, is the field of NAA's Atomics International Division. This division has successfully proved out two nuclear reactors to produce electrical power, both major advances in the drive to put atomic energy to work for mankind.

Today, in North American and its divisions, you'll find as potent a combination of scientists, engineers, and production men as any in American industry. Because they are constantly forging ahead into vital new technologies, their work holds immense promise for science and industry.

Space Age wind tunnel tests scale models in a 2,500-mile hurricane. It's first of its kind to be built with private funds.

Satellite No. 1. A Rocketdyne-built rocket engine gave the Army's Jupiter "C" satellite the critical first-stage boost toward its orbit.

NORTH AMERICAN AVIATION, INC.

SERVING THE NATION'S INTEREST FIRST—THROUGH THESE DIVISIONS

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ROCKETDYNE — Neosho, Missouri
COLUMBUS
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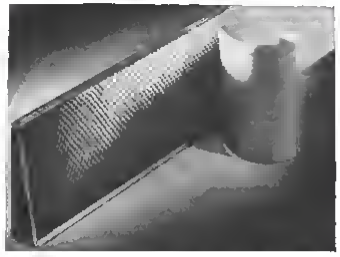
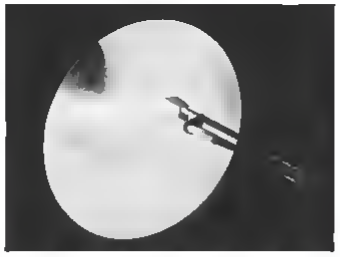
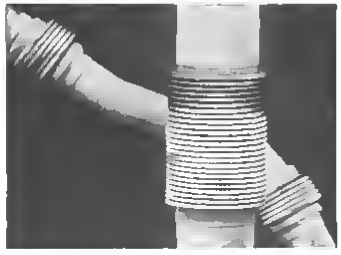
Special Solar Skills for Advanced Systems



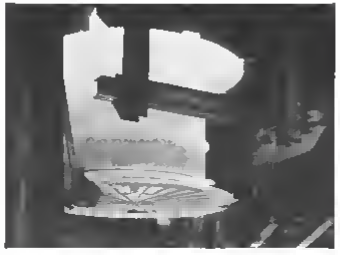
HIGH-TEMP. HONEYCOMB. Solite®—a lightweight, heat-resistant brazed steel, high alloy sandwich structure developed by Solar—has high potential for use in advanced systems.



PROTECTIVE COATINGS. Solar research and development in advanced metallurgy has produced a family of high-temperature protective coatings far ahead in the field.



EXPANSION JOINTS. Solar produces the largest array of expansion joints in the world, including complete ducting systems for aircraft, missile, nuclear and other applications.



HIGH-TEMP. BRAZING. Using hard-to-work metals and high-temperature alloys, Solar brazes stronger, lighter systems components in specially designed heat-treating furnaces.

Solar offers proven systems capabilities

Systems capabilities at Solar embrace the design, development and production of airframe, propulsion, ground support, guidance and control systems. Responsibility for Solar's systems program is centered in a team of experts experienced in the many sciences related to systems technology—from basic design to highly-precise experimental, prototype and volume production. And underlying Solar's systems capabilities is a backlog of more than thirty years of proven leadership in high-temperature metallurgy, aerodynamics, thermodynamics, combustion research and others.

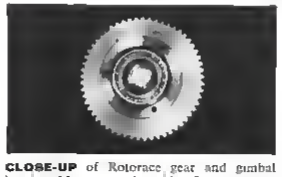
Complete manufacturing and test facilities are also available for your important systems program. For detailed information about Solar's systems capabilities, or about any of the areas mentioned above, write to Dept. F-30, Solar Aircraft Company, San Diego 12, California.

SOLAR
AIRCRAFT COMPANY
SAN DIEGO 12, CALIFORNIA

Now...a **non-floated** gyro that cuts random drift 90%

Sperry's Rotorace* Gyroscope technique

uses counter-rotating motor-driven gimbal bearings



CLOSE-UP of Rotorace gear and gimbal bearing. Motor on other side of gyro rotates outer races of opposing gimbal bearings in opposite directions reversing at predetermined intervals. Action averages out disturbance torques found in even most precise bearings.

The revelation of an entirely new engineering technique, Sperry Rotorace, now makes possible extremely accurate, low-cost gyroscopes. Reduction of random drift rate to only 0.25 degree per hour already has been achieved in systems using these gyros. And in laboratory tests, drift rates as low as 0.05 degree per hour have been achieved.

Rotorace attains this unprecedented accuracy by means of a relatively simple, low-cost method. A small servo motor rotates the outer races of two gyro gimbal bearings in opposite directions . . . then reverses the rotation periodically. Result is that friction is cancelled, errors due to minute irregularities in bearing construction are averaged out, and pitting and wearing of bearings is virtually eliminated.

Rotorace gyros make possible the accuracy of the Sperry C-11 Gyrosyn® Compasses which are now used to guide airliners where ultra-precise navigation is required—especially on transpolar and transoceanic flights. The C-11 with Rotorace gyros will also provide precise navigation for Douglas DC-8 and Boeing 707 jetliners. In addition, Rotorace gyros provide random drift accuracies great enough to enable a guided missile to hit a target 150 miles away with most probable error under 50 yards—an accuracy heretofore unobtainable with non-floated gyroscopes.

If you'd like more information on Sperry Rotorace gyros as applied to the C-11, or, if you have a special application requiring Rotorace accuracy, write our Aeronautical Equipment Division. *T.M.

AERONAUTICAL EQUIPMENT DIVISION

SPERRY GYROSCOPE COMPANY
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inertial guidance for the Navy's Regulus II

the brain behind the accuracy of the Martin Mace

now in use on the Air Force's Thor intermediate range ballistic missile

See AC

... top quality

gyros and gyro-accelerometers

now produced in volume

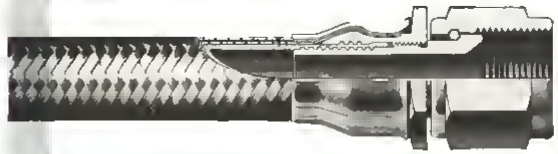
It takes all the technical know-how of American industry to produce gyroscopes in volume to the quality standards needed for inertial guidance systems. The sensitivity of the gyro accelerometers (used to sense the slightest deviation in flight) is the key to the success or failure of the missile. AC gyro-accelerometers are setting the world's highest standards of quality . . . meet minimum tolerances required . . . and they have withstood as much as 5,000 to 7,000 hours of operation without significant loss of efficiency. Gyros available for immediate delivery: 75×10^6; 10×10^6; 2×10^5; 1×10^4.

—If you are an engineer with electrical, mechanical or electronic backgrounds, contact Mr. Cecil Sundeen, Supervisor of Technical Employment, Dept. D, in care of AC . . . the Electronics Division of General Motors, Milwaukee 1, Wisconsin

Producers of: AChiever Inertial Guidance Systems • Afterburner Fuel Controls • Bombing Navigational Computers Gun-Bomb-Rocket Sights • Gyro-Accelerometers • Gyroscopes • Speed Sensitive Switches • Speed Sensors • Torquemeters

WEATHERHEAD BRAID-LOK®

Qualified TEFLON† *Hose Assemblies*



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BLOW-OFF-PROOF

EXTREME TEMPERATURE CAPABILITY

...over the full pressure and temperature range of applicable Military Specifications

...also available

"super gem"* **WEATHERHEAD FITTINGS**

REUSABLE AND FIELD ATTACHABLE

Where detachable hose ends can be used to advantage, Weatherhead offers Teflon hose assemblies equipped with high performance "super gem" fittings. These fittings can be attached or detached in the field with ordinary bench tools.

"Super gem" design assures three functions:

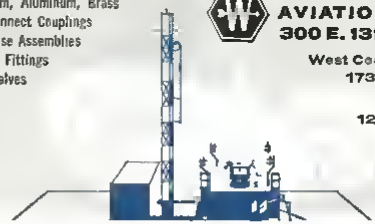
1 grips and holds the external wire braid firmly

2 seals the inner tube without compression, thus forming a lip seal

3 positive metal to metal line seal

† Teflon: Du Pont Trademark *"super gem": Aeroquip Trademark

- Titanium Products
- Aircraft Engine Parts
- Roto-Mile® Swivel Joints
- Precision Aluminum, Brass, Steel and Stainless Steel Forgings
- Coined Forgings Titanium, Aluminum, Brass
- Self-Sealing, Quick-Disconnect Couplings
- Hose and Hose Ends, Hose Assemblies
- MS (ER)® Flareless Tube Fittings
- Drain, Shutoff, Relief Valves
- Actuating Cylinders
- AN Tube Fittings
- Cluster Fittings
- Jet Nozzles



- ★ *Weatherhead Teflon hose assemblies with Braid-Lok end fittings have been qualified on the basis of conformance with all requirements of AF specification MIL-H-25579*
- Permanently attached hose ends grip the outer wire braid, locking it firmly between two metal surfaces and trapping the Teflon inner liner independently to form a perfect seal
- Specifically designed for use in fluid and pneumatic systems on missiles and aircraft. End configurations available to mate with both flared and flareless type connections
- Reliable operation at high pressures in extreme temperature range (−65° F. to +500° F.)
- Chemical inertness and resistance to corrosive action of practically all aviation fluids within the above temperature range
- Vibration and fatigue resistant flexible at both temperature extremes.
- Light and compact for fullest design utility
- Freedom from line contamination
- Non aging indefinite shelf life assured
- **High pressure Braid-Lok Teflon hose assemblies, for 3000 psi systems, now qualified and available in ¼" and ⅜" diameters . . . other sizes now in process of qualification.**

Thrusting Skyward **beyond tomorrow...**

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the ability to plan . . . . . the facilities to produce

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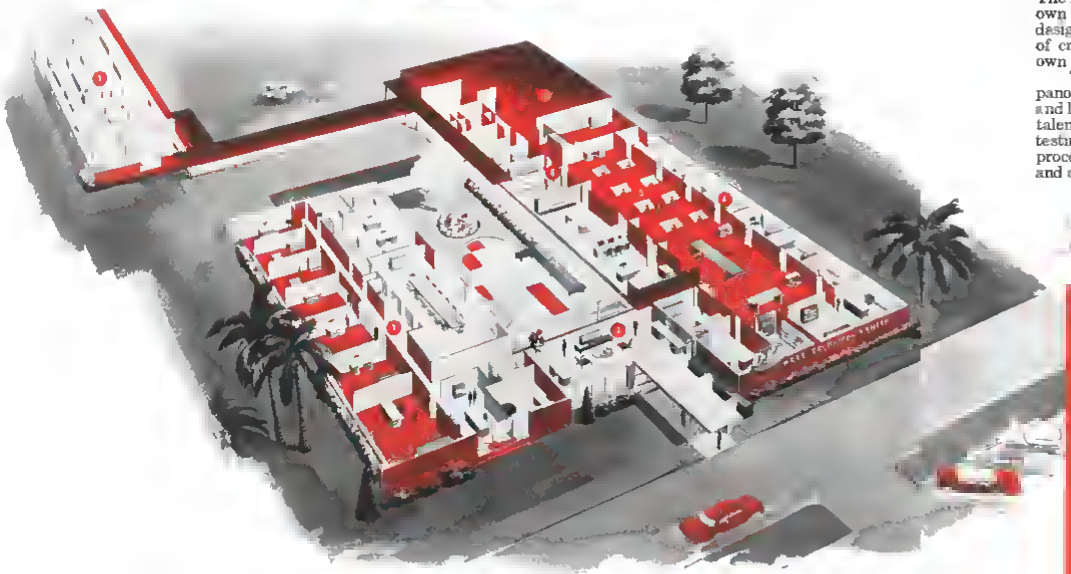

The newly completed Kett Technical Center—research and development center for U S Industries, Inc These facilities are available to help you with your on a Research and Development projects Facilities for manufacturing your product are available to you in the manufacturing divisions of U S Industries Inc

INCOMPARABLE FACILITIES FOR RESEARCH, DEVELOPMENT AND MANUFACTURING . . . AT YOUR SERVICE

Here is an unusually well organized service that can help your company plan its future products. The new Kett Technical Center, U. S Industries' own research and development subsidiary was designed from the ground up to produce the kind of creative engineering you may need for your own R & D program.

The Kett Technical Center's plant in Pompano Beach, Florida was deliberately designed and located to attract the nation's top engineering talent Complete facilities are here for designing, testing and building prototype models The data processing laboratory is equipped with digital and analogue computors In addition, a restricted area is maintained for handling all Classified work

Although the plant is new, Kett is no newcomer to Research and Development. Its achievements are already widely recognized in the fields of Nuclear, Aeronautical, Electronic and Mechanical Engineering.

In addition to Research and Development, Kett, through its affiliation with other U. S. Industries, Inc. divisions can arrange to carry out any assignment including the complete production of your product Get in touch with the Kett Technical Center by calling, writing or making a call in person

Achievements in the Aeronautical and Nuclear Fields

This supersonic pitot-static tube is used to measure air speed of high speed military aircraft Electric heating prevents ice formation in any atmospheric conditions

This automatic seal weld cutting machine is used in replacing control rod mechanisms which regulate the power of the reactor used in the submarine "Nautilus"

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SEND QUALIFICATIONS TO PERSONNEL
DIRECTOR KETT TECHNICAL CENTER

This handsome brochure describes the Kett Technical Center and manufacturing facilities of U. S Industries. Write Kett Technical Center, Pompano Beach, Florida.

KETT TECHNICAL CENTER
POMPANO BEACH, FLORIDA

KETT

division of U. S. INDUSTRIES, INC

re·li'a·bil'i·ty

n. 1. integral quality of all Com·Air products; result of imaginative design, ultra-precise manufacturing and super-rigid inspection.

When the long and costly count-down ends, will it be success, or failure? The answer can rest on the reliability of the smallest component part! Com·Air's pledge to you is absolute dependability in accessories for hydraulic, pneumatic and fuel applications ... in prompt answers to problems of pressure, flow, and actuation. Com·Air specialists are expert in research, design, testing, and ultra-precise manufacture. Example: The specialized manifolded accumulators shown below replace fuel pump and motor in a short range missile application. Saves weight, space and money. You can depend on the re·li'a·bil'i·ty of Com·Air products.

COM·AIR MANIFOLDED ACCUMULATORS
Operating pressure 6000 PSI
Temperature — 65° to +275°F
Fluid MIL — O — 5606

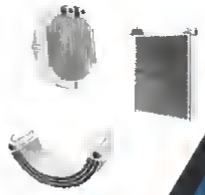
com·air
PRODUCTS
1201 RIO VISTA AVENUE LOS ANGELES 23 CALIFORNIA
A DIVISION OF A·S·R PRODUCTS CORPORATION

DESIGNERS AND MANUFACTURERS OF HYDRAULIC PNEUMATIC AND FUEL CONTROL EQUIPMENT

Circle Number 28 on Reader-Service Card

TEMPERATURE'S RIGHT FOR THE CESSNA'S FLIGHT!

Temperatures made to order for all types of aircraft engines. Harrison heat exchangers are rugged, reliable and compact ... engineered to provide the optimum in cooling efficiency.



Harrison-Cooled Cessna, Fully Loaded, Climbs 415 Feet Per Minute On One Engine!

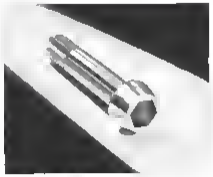
Ready for take-off ... and Harrison's ready to take care of the heat! This ultra-modern Cessna 310-B, with a host of new safety features, relies on Harrison oil coolers for sure, dependable temperature control. Harrison heat exchangers are compact, lightweight to save space and increase payload. They're specially designed to do the job and do it better. And Harrison's on every type of aircraft, from supersonic jets to private planes. You can count on Harrison, with over 47 years in the manufacture of heat-control equipment, for a top-quality product. If you have a cooling problem, look to Harrison for the answer.

TEMPERATURES MADE TO ORDER

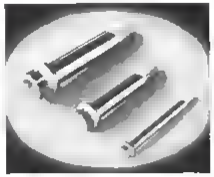
HARRISON GM

HARRISON RADIATOR DIVISION • GENERAL MOTORS CORPORATION • LOCKPORT, N.Y.

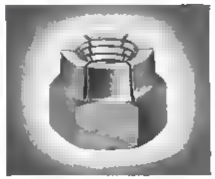
Circle Number 29 on Reader Service Card



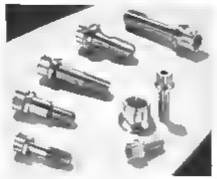
NAS 144 SERIES
INTERNAL WRENCHING BOLTS



NAS 624 SERIES
EXTERNAL WRENCHING BOLTS

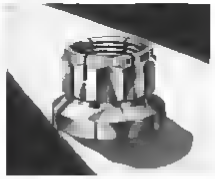


FLEXLOC SELF LOCKING NUTS

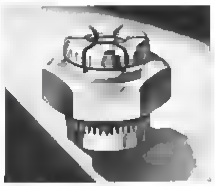


SPECIAL FASTENERS

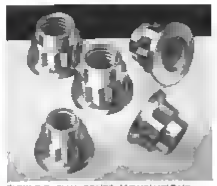
SPS HI PSI FWB 22
(220 000 psi) FASTENERS



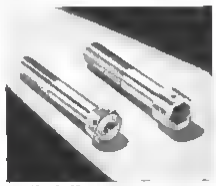
FLEXLOC EXTERNAL
WRENCHING LOCKNUTS



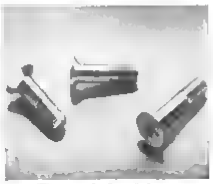
FLEXLOC SELF LOCKING
CLINCH NUTS



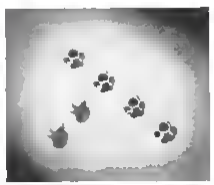
FLEXLOC FLW SERIES LIGHTWEIGHT,
HIGH STRENGTH LOCKNUTS



AN STANDARD
6 DIGIT ENGINE BOLTS

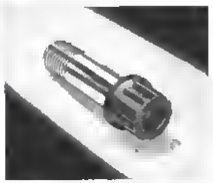


TORQ SET 180° FLUSH HEAD
SHEAR BOLTS

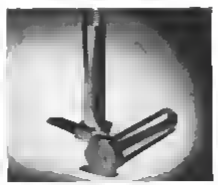


SPS SELF LOCKING
LIGHTWEIGHT NUTS

FLEXLOC HIGH
TEMPERATURE NUTS



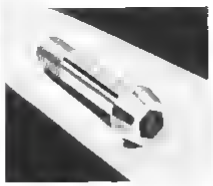
SPS EXTERNAL WRENCHING
ENGINE BOLTS



SPS HI TI TITANIUM
AIRCRAFT BOLTS

SPS EWR HI TM 9 HIGH
TEMPERATURE FASTENERS

HI-TORQUE 100° FLUSH HEAD
SHEAR BOLTS



MS 20004 SERIES
INTERNAL WRENCHING BOLTS

SPS HI TI TITANIUM LOCKBOLTS
(PULL AND STUMP)

More reliable fastening for aircraft and missiles

—proved in application

hiR High Reliability factor

At SPS we apply a dynamic standard of quality—continually refined—so that our fasteners will always have the high reliability factor required by today's faster speeds, higher temperatures, and greater dynamic forces.

This emphasis on reliability has resulted in development of fasteners with increasingly higher strength-to-weight ratios, longer fatigue life, and better resistance to the deteriorating effects of heat. Notable examples include SPS Hi Ti bolts—the first successful titanium aircraft fasteners, EWB-22 bolts—a 220,000 psi replacement for conventional MS 20004 types, and Hi Tm 9 fasteners—a unique bolt and locknut combination providing 170,000 psi at Mach 3-4 skin temperatures.

For complete information on SPS fasteners, write Aircraft/Missiles Division, STANDARD PRESSED STEEL Co., Jenkintown 3, Pa.

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Standard Pressed Steel Co. • The Cleveland Cap Screw Co. • Carbon & Steel Equipment Co. • National Machine Products Co. • Nutt Shel Co. • SPS Western • Standard Canada Ltd. • Unbrako Socket Screw Co., Ltd.

to probe high-altitude, high-temperature frontiers

. . . *CEC's 5-122 Recording Oscillograph*

permanently records 26 channels of data simultaneously (plus 2 reference traces) on film or paper

CEC'S 5-122 IS BUILT TO TAKE IT—to surpass the endurance of ordinary instrumentation. Compare this combination of environmental *operating* specifications with any oscillograph made: Temperature range from −65° to +250°F at altitudes to 120,000 feet. . . Will withstand a steady acceleration of 15 G's along any of its three major axes without interruption or deterioration of its performance . . Operates in salt-sea and dust-laden atmospheres and in a relative humidity up to 100% at +122°F. . Explosion-proof certification. . Built-in vibration isolators provide firm protective support and eliminate the need for external shockmounts.

CRASH-RESISTANT MAGAZINE. The all-important record of test results is always secure in the 5-122's record magazine. This crash-resistant unit is engineered to withstand the same abuses as the oscillograph plus a shock of 200 G's for 4½ milliseconds.

NOTHING SACRIFICED FOR ENVIRONMENTAL SPECIFICATIONS — Standard features of the 5-122 include a writing speed of more than 12,000 ips . . jump-speed selector . . flash timing . . 12 record speeds from 0.047 to 96 ips . . automatic record identification . . and provision for synchronous operation with an over-all data acquisition system. The 5-122 weighs only 80 lbs. fully loaded and is 11" wide, 8" high, 18½" long.

MASTER TIMING UNIT supplies timing pulses to the 5-122. Can control up to 10 oscillographs and may be remotely located.

CONTROL UNIT contains all controls for operation of oscillograph. Is also ideal for remote operation.

HIGH-TEMPERATURE GALVANOMETERS — CEC High-Temperature Galvanometers guarantee high sensitivity and accuracy in ambient temperatures to 250°F for extended periods. Fluid and magnetically damped types cover frequencies from 0 to 3000 cps. Write for Bulletin CEC 1528-X16.

For complete details, contact your nearest CEC sales and service office or write for Bulletin CEC 1585-X10

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The liquid-propellant booster powerplant housed in BOMARC's fuselage is another outstanding engineering accomplishment by Aerojet The BOMARC rocket booster is produced at our Liquid Rocket Plant near Sacramento

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MR. EUGENE NEGBOR, Vice President
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to provide facilities for today's sky giants... such as Hangar No. 9, for the New York Port Authority at International Airport, for **EASTERN AIR LINES!"**

"And we've found that International has the ability and experience to provide hangar doors engineered to specifications . . . designed for fast, easy operation under any climatic condition, and with lifetime weather-tightness. No wonder we've come to depend on International Service!"

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• Why not make use of International's experience in aviation hangars and doors for the project you may be planning?

INTERNATIONAL SERVICE

Test your cross-country memory

Can you name this airport?

Clue: *The Southern textile center it serves lies just east of the Blue Ridge Mountains. (Answer below.)*

Now test your aviation-oil memory: Can you give two important reasons why Gulf oils are better for your engine?

1. In addition to providing efficient, thorough lubrication, Gulf aviation oils help keep engines *clean*—and safe!

2. Gulf-clean engines can go longer between overhauls, because there's less wear and tear on engine parts.

Choose either new Gulfpride Aviation Oil Series D, the detergent oil, or Gulf Aircraft Engine Oil, the straight mineral oil—both keep your engine Gulf-clean and safe.

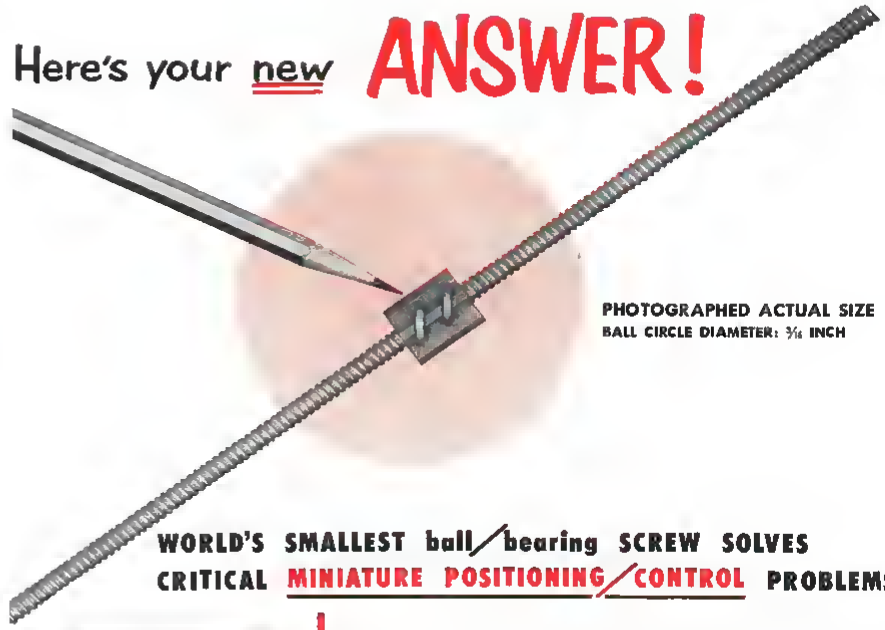
The airport is the Greenville, South Carolina Municipal Airport, a little over three miles east of the city. All runways are paved. The longest is 5,395 ft.

When you land here, we know you'll be pleased with the friendly Gulf service and the fine Gulf products available.

GULF
AVIATION PRODUCTS

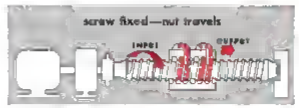
Fly safely with a Gulf-clean engine

Here's your new ANSWER!

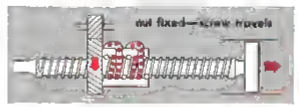


PHOTOGRAPHED ACTUAL SIZE
BALL CIRCLE DIAMETER: 3/16 INCH

WORLD'S SMALLEST ball/bearing SCREW SOLVES CRITICAL MINIATURE POSITIONING/CONTROL PROBLEMS



NUT TRAVELS: When rotary motion is applied to the screw, the b/b nut glides along the axis of the screw on ball (ingot steel balls, converting rotary force and motion to linear force and motion with 4/5 less torque than acme screws.



SCREW TRAVELS: When rotary motion is applied to the b/b nut, the screw glides along its longitudinal axis on rolling steel balls converting rotary force and motion to linear force and motion with unprecedented efficiency

An unprecedented achievement in minimum size and weight—maximum efficiency, dependability and service life for ultra-precise controls.

It's another first from Saginaw—and the possibilities it opens up for improved electrical and electronic controls are limited only by your imagination! Radar tuners, missile and rocket guidance and telemetering systems, automatic switch-gear, electronic machinery controls are just a few of the applications where this new miniature Saginaw b/b Screw will solve critical positioning/control problems. *It's so compact and light*, you can save substantially on space and weight. *It's so efficient*, (over 90%) you can use much smaller motors and gear boxes. *It's so precise*, you can position components within .0005 inch per inch of travel. *It's so dependable*, you can rely on remarkably long service life even in adverse environments.

You will find our 1958 Engineering Data Book extremely helpful in planning applications, or experienced Saginaw engineers will gladly make specific recommendations without obligation. Just phone, write or mail the handy coupon

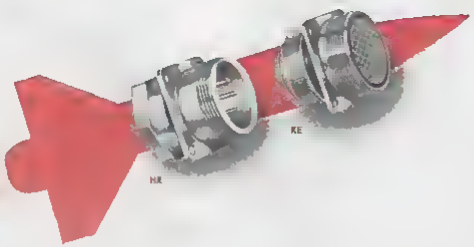
LET SAGINAW'S EXPERIENCED ENGINEERS HELP SOLVE YOUR SPECIAL APPLICATION PROBLEMS . JUST WRITE OR PHONE US—NO OBLIGATION

Saginaw ball bearing Screw

SAGINAW STEERING GEAR DIVISION • GENERAL MOTORS CORPORATION • SAGINAW, MICHIGAN

NEW

CANNON PLUGS



For greatest reliability in the hot spots

NEW HR SERIES

1000°F continuous duty type

The most advanced design to protect against extreme heat nuclear radiation and moisture formation Moistureproofing on these connectors is accomplished by means of ball cone seals on mating surfaces. Available in production quantities in wide range of MS-type shell styles and sizes Two to 24 contacts per shell Wide variety of insert patterns that mate with standard MS types A modification of the HR series, rated at 650°F continuous duty is also available

Write today for Technical Bulletin T-111

NEW KE SERIES

Moisture-resistant firewall type

First plug to satisfy both high-temperature requirements for fireproof Class MS-K connector and vibration-proof, moisture-proof requirements of MS-E Class Meets 2000° flame test specified in MIL-C-5015—stands up under 400°F continuous operation Fluorinated silicone seals for moisture proofing improve resistance to oil and skydrol hydraulic fluid Two basic shell types for conduit and wire bundles Wide variety of insert arrangements and shell sizes in long and short types

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Call on Cannon for *all* your plug needs If we don t have what you want, we'll make it for you—whether you need one or a million We're ready to help you at any stage—from basic design to volume production—with the largest facilities in the world for plug research, development and manufacturing Write us today about your problem Please refer to Dept. 110.

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CANNON ELECTRIC COMPANY

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...aviation's standard transparent plastic

PLEXIGLAS is a trade mark, Reg U S Pat Off. and in other principal countries in the Western Hemisphere

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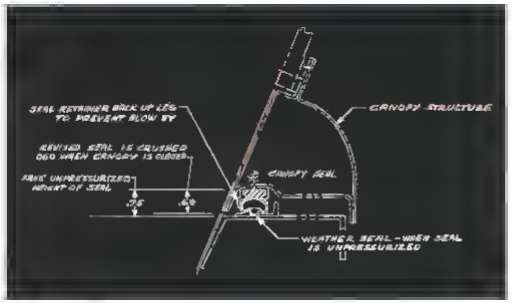
The PLANE

Convair's F-102A, USAF single-seat, supersonic, all-weather, delta-wing fighter. The F-102A was the first of Convair's supersonic delta wings to become operational. It is powered by one Pratt & Whitney J-57-P-35 turbojet, with afterburner.

The PROBLEM

Canopy seal. A positive seal must be maintained between canopy and fuselage to hold cockpit pressure. The seal must stay resilient when exposed to extreme temperatures at flight altitudes; must also resist a relatively high concentration of ozone.



The PART

SILASTIC
SILICONE RUBBER*

Silastic*, the Dow Corning silicone rubber, was specified for this seal because of its elasticity at —130 F; its resistance to ozone, moisture, and extreme temperature cycling; and its low compression set. Silastic will meet your seal requirements, too: ask your rubber supplier for further information, or write Dept. 096.

*T.M. REG. U.S. PAT. OFF.

first in silicones
Dow Corning
CORPORATION
MIDLAND MICHIGAN

FLEXIBLE CONNECTORS, in a variety of sizes, constructions, materials, are designed to meet many working conditions. Our sales representatives in cooperation with our engineering design service will be glad to be of assistance.

BIG space-age problems get BIG flexible metal tube answers

Large-diameter flexible metal connectors in stainless steel and other alloys—to handle expansion and contraction, wide range of temperatures, corrosive fluids, high pressures, and vibration.

Jet engines, modern chemical plants, rockets, atomic energy plants have created a new technology that calls for new products. The American Metal Hose Division of The American Brass Company is constantly working with design engineers on special flexible connector assemblies to meet new problems.

Equipped to work in stainless steel, Monel, and aluminum as well as in other alloy steels and copper alloys, these Anaconda specialists welcome the opportunity to help you get the flexible metal hose you need to meet your problems of expansion and contraction, movement, vibration, corrosion, pressures, and temperatures.

FREE TECHNICAL SERVICE For engineering assistance on special products—or for a free copy of our General Catalog showing the full line of standard American Flexible Hose and Tubing products—write The American Metal Hose Division, The American Brass Company, Waterbury 20, Connecticut.

WHEREVER CONNECTORS MUST MOVE

AMERICAN
FLEXIBLE METAL HOSE AND TUBING
an
ANACONDA®
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Please send me your free, 60-page General Catalog containing basic information on all types of metal hose and tubing, fittings, etc.

NAME & TITLE .....

ADDRESS .....

COMPANY .....

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(PLEASE PRINT OR TYPE)

PIONEERS OF THE THERMAL FRONTIER

Eastern
COOLING ELECTRONIC SYSTEMS FOR MISSILES

Monsanto
NEW FLUIDS FOR THE MISSILE AGE

advanced
system of **COOLING ELECTRONICS**
extends missile performance

EASTERN AVIONIC COOLING SYSTEM IS LIGHTER . . . SMALLER . . . MORE RELIABLE

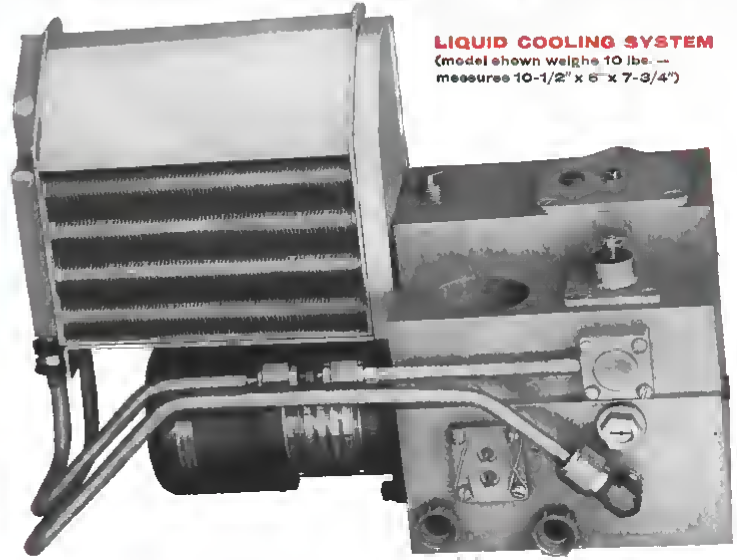
Electronic equipment is vulnerable to the fantastic heat encountered by missiles. Eastern liquid cooling and refrigeration systems maintain safe avionic operating temperature limits even in the 800°F. environment present at *five times the speed of sound.*

MINIATURIZING ALL COMPONENTS

In addition to efficient, reliable operation, Eastern cooling systems are miniaturized to meet the most rugged missile requirements for space and weight. By using Monsanto Coolanol 45* fluid, a 24,000 RPM hydraulic pump no bigger than a fist can be used. Coolanol 45 keeps the high speed pump lubricated, as well as providing a coolant with outstanding qualities. The high boiling point of Coolanol 45 permits a smaller system since temperature maintained can be higher. Coolanol 45 is an excellent heat-transfer medium with good dielectric properties. Adequate viscosity assures long life of precision hydraulic pumps. Systems are easily sealed to prevent contaminating air leakage, and the low foam tendency of Coolanol 45 minimizes circulation troubles.

DESIGNS TO MATCH MISSILE PERFORMANCE

Using a basic liquid cooling system, or by adding refrigeration cycle, cold plates, or evaporative cooling as needed, Eastern can protect electronic equipment under the severest temperature conditions. Come to the leader in the field for *complete* and *creative* help



LIQUID COOLING SYSTEM
(model shown weighs 10 lbs. — measures 10-1/2" x 6" x 7-3/4")

Eastern subsystems and systems for missiles and aircraft

AVIONIC COOLING • REFRIGERATION • HYDRAULIC POWER PACKS • PRESSURIZATION DEHYDRATION

For bulletin 0-123 on Coolanol 45, write

Monsanto
MONSANTO CHEMICAL COMPANY
Aviation Fluids Dept. AV-3
Lindbergh and Olive Street Road,
St. Louis 24, Mo.

*Coolanol 45: Monsanto trademark (formerly OS 45)

For aviation bulletin 350, write

AVIATION PRODUCTS
EASTERN INDUSTRIES, INC.
100 Skiff Street
Hamden 14, Conn.

Circle Number 40 on Reader Service Card

Guiding a missile, or speeding flight and flight environmental data back to control and tracking centers, is too much of a job for conventional communication systems. Supersonic speeds call for lightning fast data communications, coupled with the utmost reliability.

Capitalizing on the ease of converting messages into digital form, Motorola scientists and engineers have developed a number of Data Link Communications Systems suitable for piloted aircraft, as well as missiles.

NERVE CENTER FOR DATA LINK SYSTEMS

With Data Link Systems, messages that have been translated into on-off pulses can be transmitted by any of the common modulation schemes with a suitable carrier. The transmitter can be air-borne, ship-borne, or land-based. Received messages are amplified, decoded, and transformed into a form suitable for display, or stored for some future time, or used for direct control through auto pilots, for example.

One of the Data Link Systems designed at Motorola utilizes an all-transistor converter-coupler, packaged in modular form. The total system consists of eight modules, each approximately 4" x 8" x 1½". The fully transistorized circuitry is of the highly reliable diode-matrix type logical circuitry used in many digital computers. The switch type transistors employed are a product of the Motorola Semi-Conductor Division. Indicative of the stringent testing program to which the transistors are subjected is a 1000-hour life test at 85° C.

For another Data Link program, Motorola has designed a system featuring resolver-type outputs. A single time-shared servo amplifier positions anyone of the five resolvers in accordance with commands from the ground transmitter.

These two Motorola Data Link Systems aimed at solving one of the important communication problems of the missile age are examples of the complex programs conducted by Motorola for varied military needs.

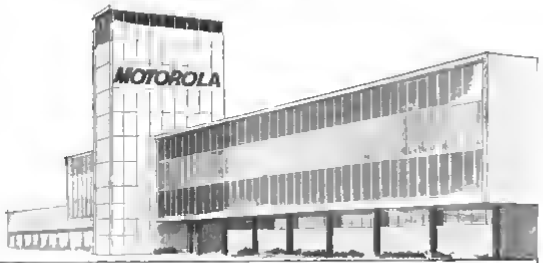
MOTOROLA INC.

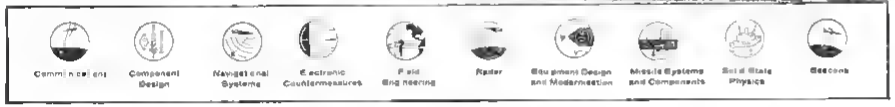
MILITARY ELECTRONICS DIVISION

Chicago Area Center • 2710 N. Clybourn Ave. • Chicago, Ill.

Western Area Center • 8201 McDowell Road • Phoenix, Arizona

Positions open to qualified Engineers and Physicists





QUALITY PERFORMANCE EXPERIENCE

in a light weight package

In defense preparedness and space conquest programs, Stewart & Stevenson Ground Support Units offer the maximum in performance characteristics and dependability. They are light weight, compact, provide greater accessibility, low noise level, minimum maintenance.

This Stewart & Stevenson All Weather 45 KW, 400 Cycle AC Diesel Ground Support Set, with an electric load sensing governor, is typical of those being used in our missile and defense programs.

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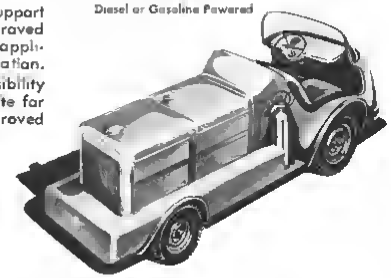

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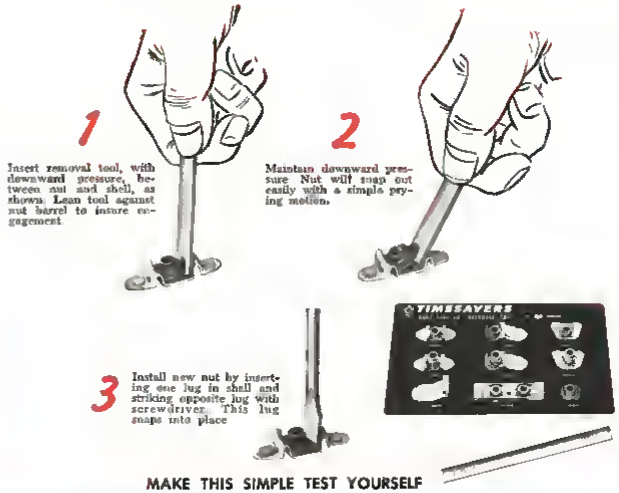

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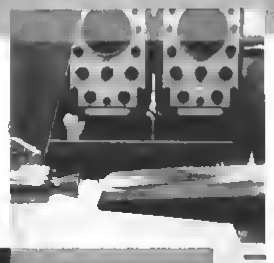

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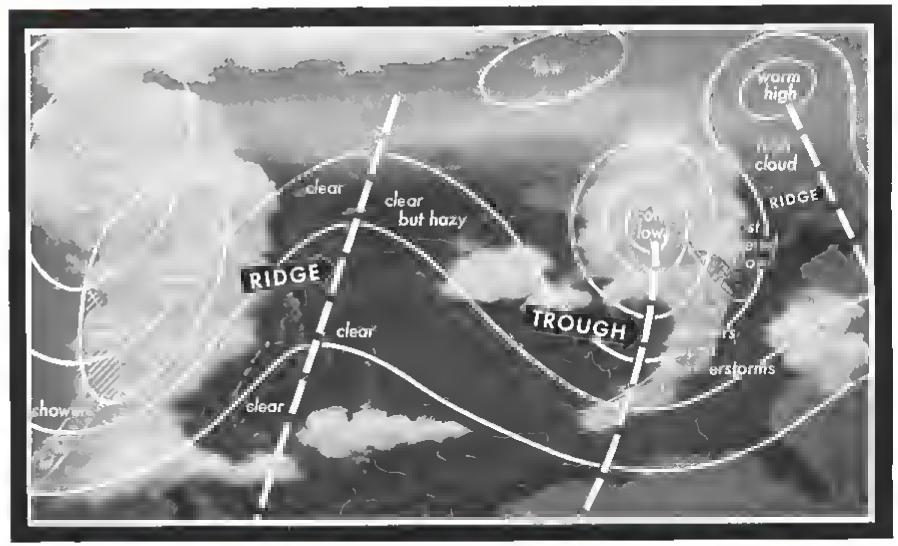

CIRCULATION PATTERNS

Clockwise circulation of air around High Pressure areas and counter clockwise flow around Lows in the northern hemisphere are well known to most pilots. However, there are some lesser-known features of Highs and Lows which have become apparent with the progress made in upper air analysis.

Warm Highs—Extend to levels above 10,000 ft. with temperatures generally warmer than Standard Atmosphere. As this type of High extends farther aloft, it often assumes an elliptical shape with major axis lying N/S to form a *Ridge*. This Ridge normally moves very slowly, blocking eastward movement of weather systems at lower levels, often causing prolonged periods of fair or rainy weather in adjacent areas. Weather in warm Highs is usually dry, fair and often hazy.

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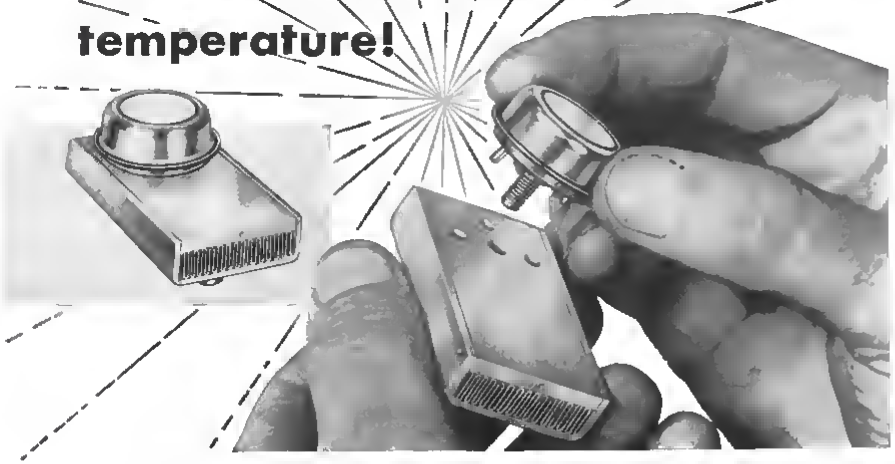
UAP COLD PLATE controls TRANSISTOR junction temperature!



minimizes transistor derating for thermal conditions . . .

UAP cold plate U-521330, designed for Collins Radio Company, dissipates heat generated by power transistors used in ground and airborne electronic circuits. The heat is transferred across a pressure thermal contact to cooling air. The cold plate controls the transistor junction temperature within operating limits compatible with the installation. Therefore, transistor derating is minimized.

The cooling air, which is forced through the cold plate, can be ducted from an air cycle refrigeration system, a ram air supply, an air manifold within the electronic compartment or a pressurized equipment package.

The aluminum cold plates are bonded by UAP's dip braze method which produces extremely lightweight assemblies with maximum heat transfer area within the core. Cold plates can be used individually or assembled in manifolded banks.

DESIGN PERFORMANCE CHARACTERISTICS OF U-521330 COLD PLATE
Air flow: 7 lbs per hr
Air pressure drop: 0.25 H_2O corrected to .0765 density
Temperature drop in cold plate: 1.5°C per watt dissipated
Weight: Approximately 1 oz
Performance characteristics can be modified to requirements

For complete information call the nearest UAP Contractual Engineering Office

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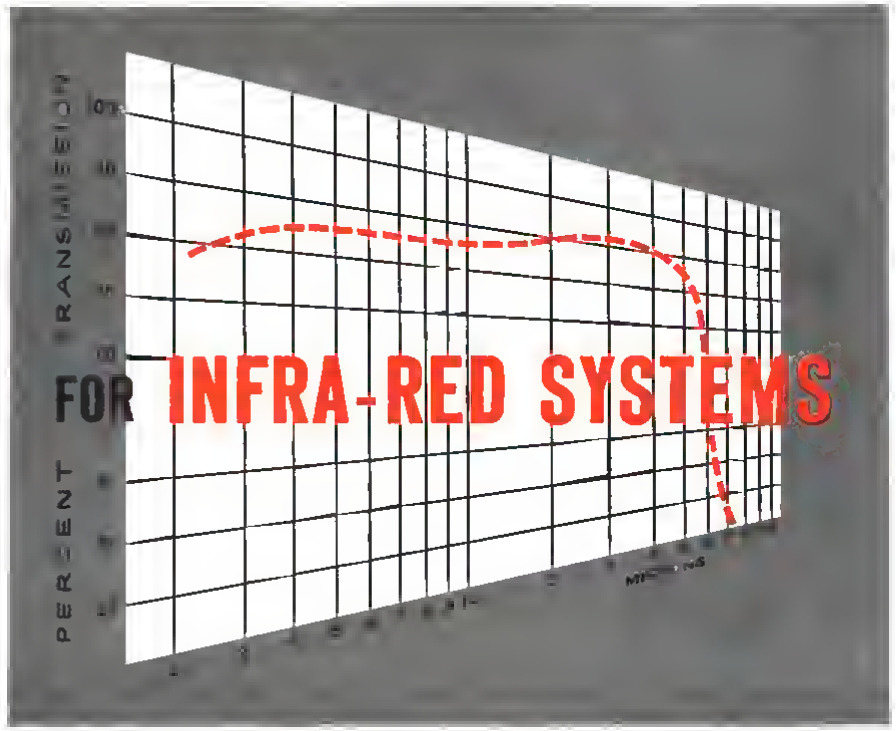

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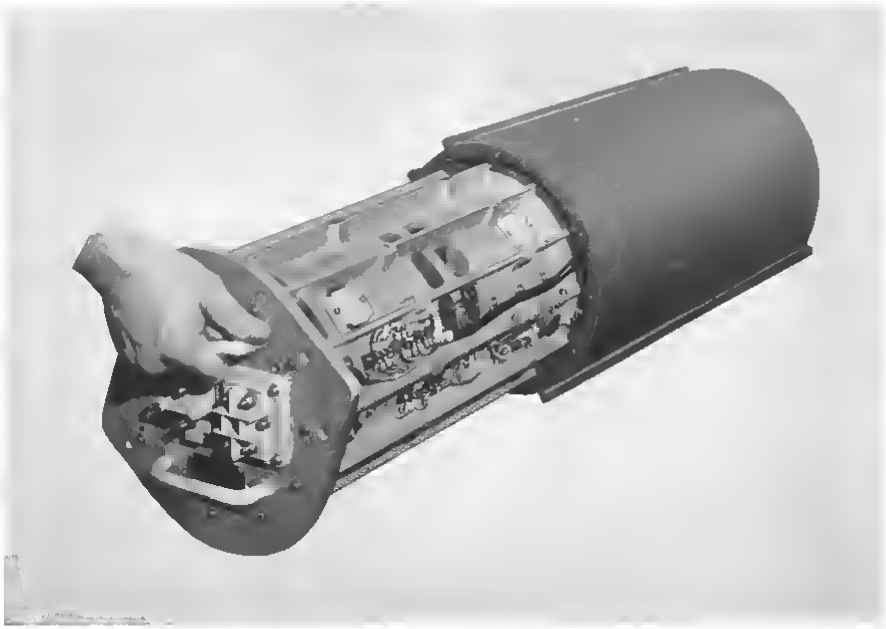

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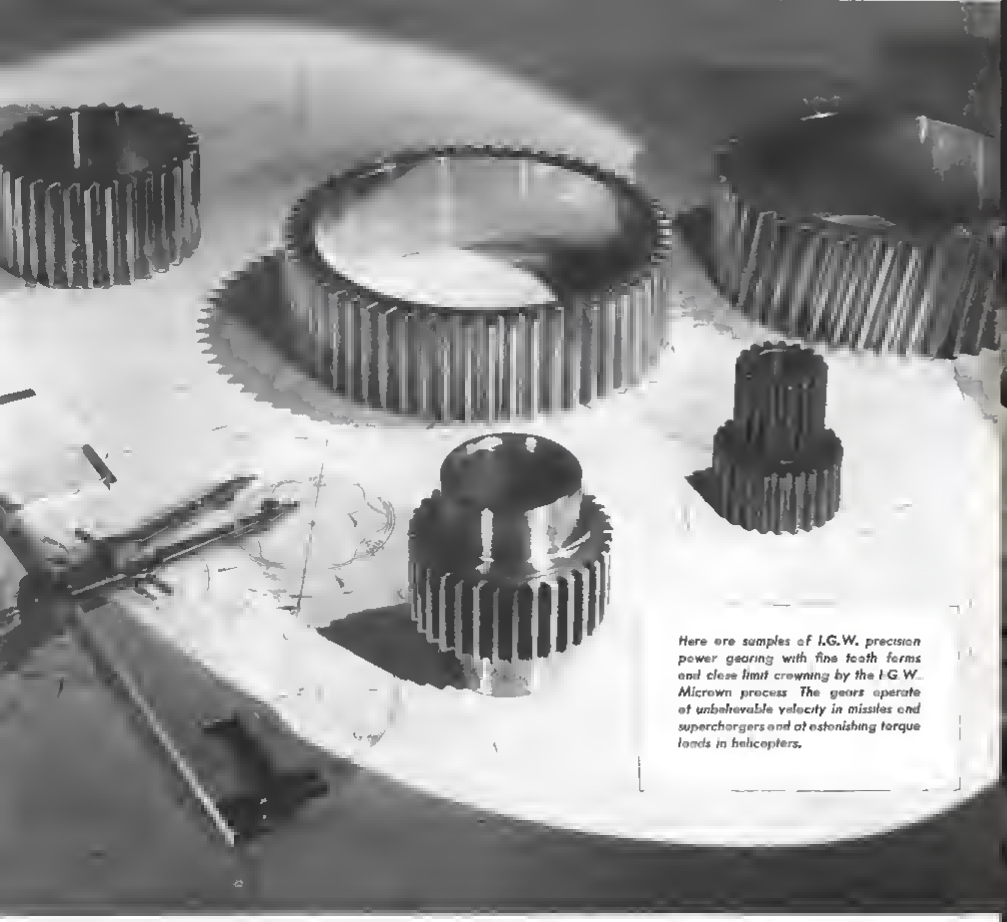

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Including Space Technology

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RESEARCH FOR SPACE EDITION

COVER Thor-Able test vehicle for re-entry and lunar probes is launched at Cape Canaveral, Fla.

Meeting the Challenge of Space

Exploration of outer space poses one of the greatest scientific challenges of the next half century. This challenge is two-fold. First, it will challenge U.S. executive and administrative ability, an area in which recent falterings have been critical, to organize the national technical effort on a scale and with the speed needed to surpass all international competition. The second aspect of this challenge is the opportunity to pry loose a vast new area of vital knowledge about our universe that can be used to benefit mankind. The U.S. already is off to a late start in this effort. We must face the harsh fact that the Soviets' three Sputniks have shown us, plus the rest of the world, that we face stiff competition based on a sound scientific foundation plus the vital ingredients of national enthusiasm and level political support.

Stakes in the race for successful exploration of outer space are high. First is the international prestige in exhibiting top ability to make available scientific data that could yield vast civil benefits—improved communications, weather forecasting and many other as yet unforseen applications of space knowledge. Second is the projection of the fierce technical competition in weapons development in the field of aeronautics and missiles into space where the key to mastery of this planet for good or evil may lie.

It is far too early to accurately assess the military value of space. A rational settlement of arguments now raging over the possible military value of space operations cannot be reached until far more sound scientific data is available to replace the vast number of purely theoretical hypotheses now being propounded regarding outer space. The most urgent need now is the organization of a sound and truly national effort to push as hard as possible a methodical exploration of space to yield maximum useful data in minimum time. There is no question that the U.S. has the scientific talent plus engineering and industrial ability to take the lead in this space exploration effort if given consistent financial and political support and a sound organizational pattern to allow the full scope of the best available talent in this field.

CRITICAL PROBLEMS

Inadequate organization and top level governmental support are now more critical problems than the scientific aspects of space exploration. It is interesting to note that the Soviets have had a formal space exploration organization existing since 1955, and support for the rigorous Russian space exploration program comes from the Soviet Presidium where 60% of the membership of this top political group has a technical education of some kind. Early appeals for some sort of U.S. national space program by technical professional groups such as the American Rocket Society were largely ignored until the advent of the International Geophysical Year and clear indications of a strong Soviet space contribution. This effort finally sparked organization of the Vanguard satellite project. As a matter of record, it must also be noted that the U.S. Army and Navy had proposed satellite programs much earlier than the Vanguard, utilizing existing hardware. These proposals never surmounted the barriers of technical timidity then existing top levels of Department of Defense leadership.

USAF also has had a space research program operating in the Air Research and Development Command since the early 1950s. A proposal to organize a major space program, using Holloman Air Development Center facilities as a nucleus, was submitted by USAF more than three years ago and firmly rejected by top level Pentagon leadership.

With the technically interesting but organizationally unsound Vanguard decision to attempt to separate science from military research behind us, there are now some solid encouraging signs on the space horizon. President Eisenhower's proposal to organize a national space agency under primary civilian control but with close military ties and utilizing existing personnel and facilities of the National Advisory Committee for Aeronautics was a firm step in the right direction. It is gratifying to see strong congressional support for the basic elements of this proposal, although there has been some legislative carpentering necessary to emerge with the best possible position for this new agency. We have strongly supported this proposal to establish a truly national space exploration program under civilian control and using the nucleus of an aeronautical research group that already has an international reputation for sound scientific achievement, plus the integrity vital in working closely and effectively with all other aspects of national life that must be included in a truly sound space exploration program.

CONFIDENCE IN NACA

We have full confidence that the present top leadership of NACA in Dr. Hugh Dryden and Dr. James Harold Doolittle has the type of dynamic imagination needed to transform their organization into an effective tool for the new tasks facing it in space. We predict they will make a strong effort to bolster this leadership with an influx of younger and technically bold personnel capable of generating the enthusiasm required to spark this effort plus the ability to chart a sound scientific course. We also predict the leadership of the new space agency will have the courage to firmly reject circus-stunt-type projects aimed at maximum publicity and minimum scientific value.

Major keynote of the new national space policy sounded by a special House committee headed by Majority Leader John McCormack is for freedom of information gained in space exploration. This positive policy of widespread dissemination of data gained by exploratory effort is a long needed reversal of the dark secrecy policy generated by the Atomic Energy Commission that has done so much to slow the U.S. rate of technical progress. The policy of a maximum flow of scientific space data is vital to maintain maximum progress across the board in this field. The committee members deserve commendation for the thoughtfulness of this approach to the problems of creating a national space agency, their earnest efforts to achieve some semblance of technical literacy and understanding of the basic issues involved plus the speed and decisiveness with which they acted. Their performance in this area is heartening reassurance that the democratic process can really cope with modern technical problems when given positive and enlightened leadership.

The major problem facing a new space agency will be the integration of all the now-separate elements of the military and civil research and development spectrum that can usefully contribute to national space exploration programs. There is no single military service, no area of civilian specialists, that has a monopoly on either ability or enthusiasm in the space field. NACA already is devoting a major part of its effort to space and related missile research. At the technical level, Army's Redstone Arsenal group is capable of continuing significant contributions to the space program. In view of Army's increasing dependence on industry for development of missile weapon systems, it may be a good idea to incorporate Redstone's technical nucleus who always have been prime space enthusiasts, into the new space agency in some manner where their talents can continue to flourish. Navy also has sound contributions to offer the space program, particularly in human factors and communications. The whole broad spectrum of USAF space exploration capability must be utilized, ranging from space medicine through geophysics and rocket powerplant developments.

NEED FOR UNIFICATION

Here is a good beginning for true unification of military research and development efforts. This is no need for three separate space research programs, each wearing a different military uniform and under a different military command. If such military requirements develop that make a space force necessary, it should be a single unified effort, not a carryover of the technically obsolete land, sea and air division now confounding efforts to develop a sound defense posture for the future. Unification of military aspects of the space program, however, does not mean elimination of sound competition and varied approaches in exploratory research and preliminary development phases. This is vital to a sound space research program. Congress and the American public should be careful to detect the difference between sound competition and a multi-approach policy in the research and development stages and the necessity for unified application of data obtained to weapons procurement and operation. It is absolutely essential that U.S. industry, universities and research organizations play a vital part in the national space program.

The new space agency cannot do all the necessary work in its own laboratories or with its own personnel. Their main function should be leadership, organization and guidance, with the bulk of actual research, tool development and exploratory research utilizing the best available talent wherever it can be found.

What should be the scope and priority of the national space research program? This is a vital question yet unanswered in policy developments to date. There is likely to be an area of considerable conflict as the program develops. There is still a strong element of technical conservatives allied with special interest axe grinders who are hopeful of putting the brakes on space research. Their reasons range from genuine concern over the relative value of space research as compared with other possible development areas to a simple desire to halt the bandwagon until they can gracefully climb aboard.

Congressional debate has indicated that the initial space agency programs will cost about a half billion dollars annually, climbing soonest to a billion dollar annual level. This estimate is as good as any now available but will bear modification in the light of initial experience and the pace of the data harvest from the early program. We must consider as a primary fact in gaging the scope of the space research program that we have lost an enormous amount of valuable international prestige among our allies, neutrals and enemies by our initial fumblings and by the obvious lack of dynamic leadership that has been a hallmark of U.S. efforts in technical areas for the last 20 years. Our space research must be aimed at regaining lost ground and establishing a clear cut continuing future superiority. This can be done by a soundly conceived, vigorously executed, consistently supported program rather than by a frantic crash program whereby we vainly try to buy irretrievably lost time with money.

WHERE TO BEGIN

Where do we begin? We already have a sound, if not spectacular start with the Vanguard project and Army's Explorer program. Already we have harvested data from these efforts, filling in with facts areas of prior ignorance or speculation. It is obvious that we must build the next steps on another sound foundation of ballistic missile powerplant and guidance development. Lunar probes now being developed by Army and USAF using Jupiter and Thor propulsion for the initial stage for launching offer a good example of using existing hardware combinations as exploratory research tools. The space research program must be a step by step, painstaking probe into each unknown area to yield data that, when put together, will give us a sound basis for development of both civil and military applications.

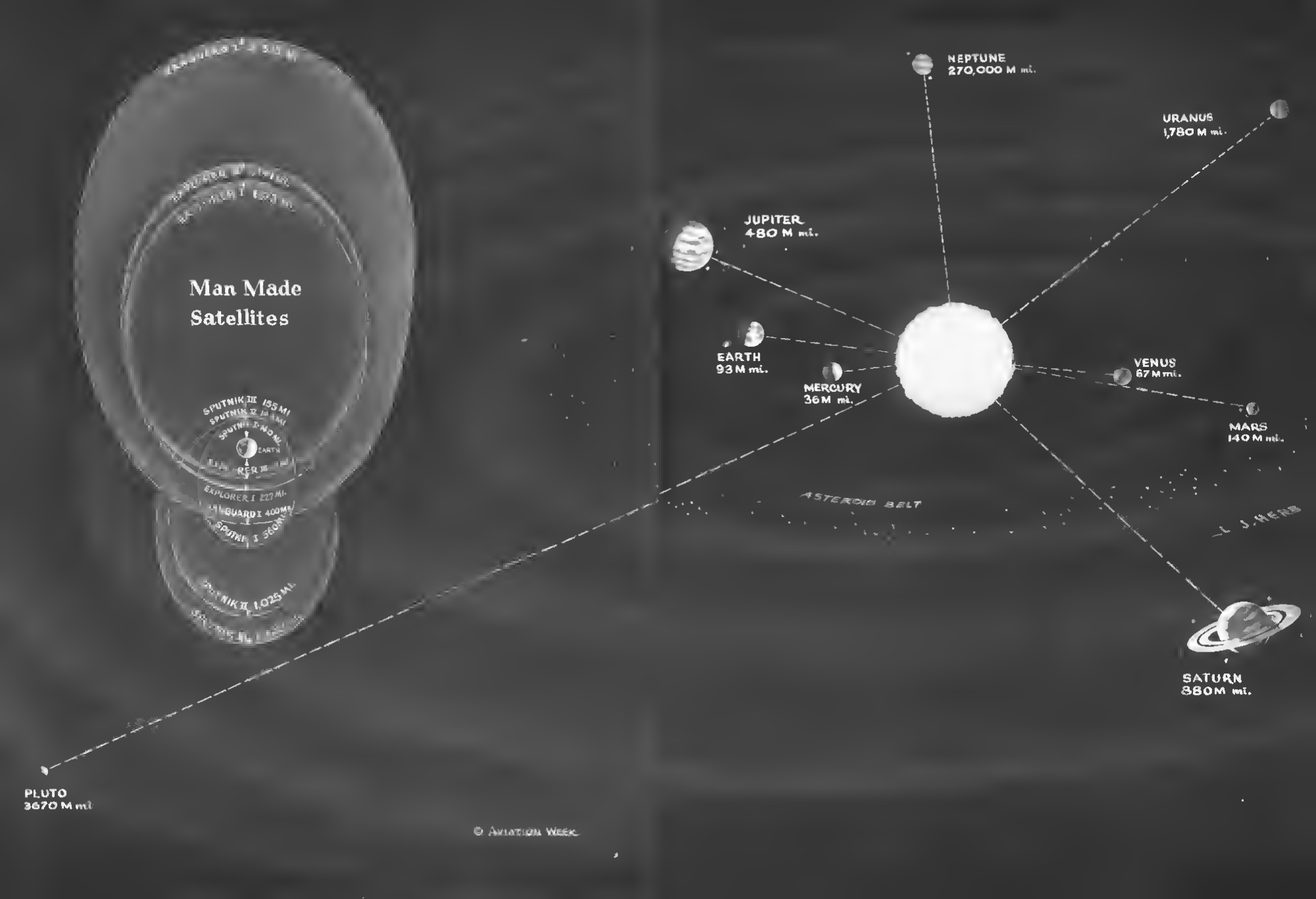
Still using ballistic missile dividends, the next step should be experimenting with man in space to determine his capabilities and limitations. It is utterly futile to debate the necessity for a man-in-space program. Until we get man in space to determine what he can do there, we will have absolutely no real idea of future possibilities of space operations. Beyond these initial explorations already loom more sophisticated programs for putting manned space vehicles into orbit and using new forms of propulsion for space travel. We can already see in the field of propulsion nuclear rockets and new forms of chemical rockets on the horizon that will make possible many space projects that are now only hopeful dreams.

LESSON TO BE LEARNED

We will experience many failures along the way to space exploration. Men will pay with their lives and reputations for these failures, but that must not deter us from pressing onward toward the goal of ultimate success. As a nation we have worshipped too long at the shrine of material success to understand fully the significance of experimental scientific failure. But it is a lesson that must be learned if space and other scientific exploration programs are to proceed without serious public and political harassment.

Thanks to the jolt of the Soviet Sputniks, we are now facing the realities of a space exploration program. But we cannot hope to be successful in any area of scientific development or in the exploitation of basic new knowledge if our efforts are sparked only by external stimulus. We must have the imagination to chart our own course and the courage to stick to it despite inevitable failures of early experiments and rising costs as the program develops. All this will require rigorous enlightened leadership by the national space agency plus sound, sustained public support. The main problem now is to lay a sound scientific foundation of basic new knowledge on which an active space program for the future, both military and civil, can be built.

—Robert Hotz



Principal Government Research and Development Centers

Research Reveals New Problems in Space

By James A. Fusca

As man prepares for the greatest adventure of his short recial history—escape from the confines of earth's gravity—questions as to what the environment of space is really like are among the key questions of present-day space technology.

As rockets and balloons explore the upper atmosphere and satellites, both large and small, maintain a precarious equilibrium in cislunar space, some of the answers are being found. These answers, however, are upsetting our conventional theories as to the nature of space and raising problems far more complex than any that they are solving.

Perhaps three of the most interesting considerations to emerge from the present intensive scientific study of the space environment are:

• **Earth-sun relationship.** Importance of the relationship between earth's upper atmosphere and the sun is becoming increasingly apparent. A new theory developed by Dr. Sydney Chapman, who headed the committee that organized the IGY, holds that the sun possesses a tenuous atmosphere that extends through interplanetary space beyond the distance of the earth's orbit. This solar atmosphere consists mainly of ionized hydrogen, protons and electrons, with a density at earth's distance from the sun at about 1,000 particles per cubic centimeter.

• **Magnetohydrodynamic theory.** Combining the theories of electromagnetism and hydrodynamics, magnetohydrodynamics (the study of the interaction between magnetic fields and electrically conducting fluids and gases) offers what may be today's most exciting area of study in all of science—offering possible solutions to problems extending from controlled nuclear fussion to the origins of life.

• **Earth's magnetic field.** For the last three hundred and fifty years it has been known that the earth is a giant magnet. Conventionally, the earth's external magnetic field has been considered to resemble that of a bar magnet or "dipole." Cosmic ray studies analyzed at New York University suggest that this concept is erroneous, and that magnetohydrodynamic effects displace (drag behind) the lines of force as much as 45 deg. to the westward as the earth rotates.

Earth-Sun Relationship

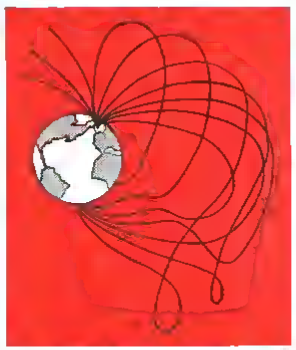
Earth's atmosphere decreases upwards in density until it merges with the very thin solar atmosphere. X-ray and ultraviolet radiations from the sun ionize (break into positive and negative particles) layers of the earth's atmosphere at altitudes between approximately 60 and 200 mi. Density of ionization increases during daylight hours and decreases at night.

As the earth rotates the number of charged particles at any one point varies. Under the influence of the earth's magnetic field, very large electric currents are generated in these ionized layers that flow around the earth at right angles to the magnetic lines of force.

Three of these currents are known to exist. One circles the equator and two others the north and south magnetic poles. Magnetic effects observed during the so-called magnetic storms are believed to originate in these rivers of current.

The upper atmosphere also is bombarded at all times by particles radiated by the sun. During periods of sun spot activity, however, this bombardment increases to the point where much greater ionization takes place in the lower ionization layers of the atmosphere with a consequent large increase in absorption of radio signals over a wide range of frequencies.

One type of anomalous propagation under study is that of "whistlers"—very low frequency radio signals generated by lightning strokes that follow the earth's lines of magnetic force from one hemisphere to a similar point in the opposite hemisphere. Existence of solar whistlers, generated by electromagnetic activity in solar eruptions, has been proposed as an explanation of certain periodic fluctuations in the earth's magnetic field.



DISPLACEMENT of the earth's magnetic lines of force caused by opposing field set up in space as the earth rotates

As the earth-sun relationship is better understood, many of the basic problems of space flight and space communications will be closer to solution.

The ionized solar atmosphere is an electrically conducting medium. This means that the rotation of the sun and planetary bodies such as the earth set up electric currents in space that develop magnetic fields of their own. These fields interact in turn developing an order of complexity that has been described as attempting to deal mathematically with six dimensional vector space.

Stanford physicists have stated that devices for generating electromagnetic energy have employed electrons almost exclusively. They say that this appears to be an artificial restriction upon the potential of electronic devices. They indicate that the use of fully ionized plasmas and ionic energy as a means of improving the noise level and efficiency of microwave systems seems very promising.

Understanding of the behavior of electromagnetic energy in ionized gases will be one of the first requirements for communications through interplanetary distances. Development of new techniques for generation of extremely high power signals and very low noise level receivers will be the second requirement.

Earth's Magnetic Field

Earth's external magnetic field has conventionally been considered to resemble that of a bar magnet located about 200 mi. from the center of the earth and tilted by 11.4 deg. from its axis.

New York University's Dr. Arthur Beiser has developed a different model of the external field, however, based on analysis of cosmic ray data gathered as part of the U. S. IGY program.

Based upon the fact that rotation of the earth's lines of magnetic force through the conducting medium of the solar atmosphere induces current in it in the same manner as in a dynamo, the induced currents out to a distance of 10 earth radii develop a magnetic field of their own, creating a magnetic drag that is believed to be the primary force that is slowing the rotation of the earth at a rate of 0.0016 seconds per century.

This drag displaces the earth's lines of magnetic force in a westward direction up to 45 deg. at the equator. Not only would such a displacement explain the distribution of cosmic rays but also anomalies as to the radiation point of auroral coronas and other auroral phenomena. ■

TEST MODEL glows at 2,000F and 2,000 psi in pebble bed heater at NACA's Ames Aeronautical Laboratory.

Space Agencies

SPACE programs proposed by NACA include launching of lightweight inflatable spheres that will be visible to the naked eye.

NACA Shifting to Space Agency Role

By Robert Hotz

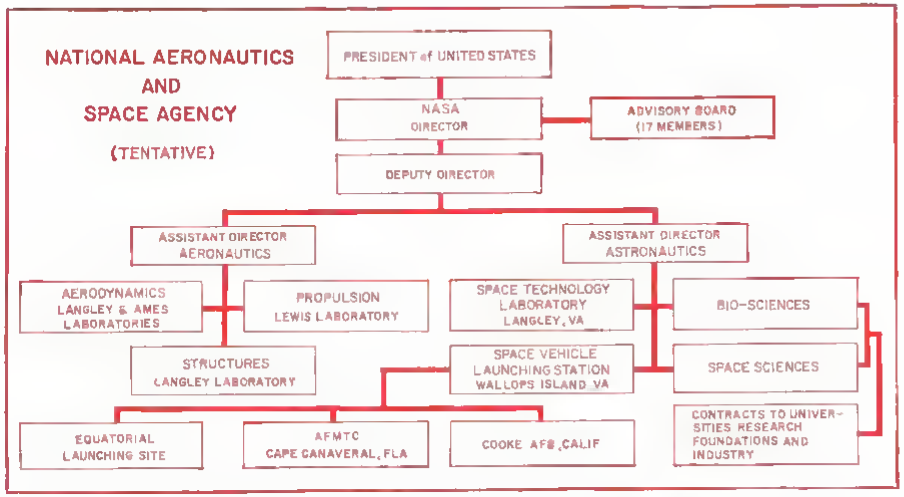
Creation of a National Aeronautics and Space Agency to spearhead a national program of space exploration and research should emerge from the congressional crucible before the end of the current session. This represents a belated decision on the part of the United States government to formally organize a permanent national space effort. It comes just three years after the Soviet Union created an organization of scientists with similar goals.

Congressional hearings on the basic proposal submitted last April by President Eisenhower have shown general agreement with the idea of using the present National Advisory Committee for Aeronautics as the nucleus of the new space agency. However, there has also been unanimous agreement by the House Select Committee on Astronautics and Space Exploration that a much stronger set of legislation is needed to properly establish the new agency on an operationally efficient basis than was submitted with the President's message.

Utilizing the 8,000 scientists and four great research installations of the National Advisory Committee for Aeronautics along with its more than 30 years of dealing with both military and civil agencies on aviation problems should save at least five years' time and untold millions of dollars over any attempt to create a new space exploration agency from scratch.

There are, however, several fundamental changes that will be required in the traditional role of NACA as it steps into the full responsibility for the space program. These include:

- **Reversal of the role** of director and the 17-man advisory committee. The committee, which now appoints the director, will become advisory to him. The director will be appointed by the President with Senate confirmation and will have full executive direction of the agency.
- **Extension of contract work** with universities research foundations and industrial groups for basic research and development in the variety of fields included in the broad spectrum of space technology.
- **Expansion of some present NACA facilities** to increase the scope of their current work in space technology. The research missile firing facility at Wallops Island, Va., and the Lewis Flight Propulsion Laboratory at Cleveland, Ohio, probably will bear the brunt of the initial expansion. Because of the close proximity of Wallops Island to Langley Aeronautical Laboratory, it is likely that Langley will become more space-oriented to complement the work at Wallops Island.
- **Formalization** and strengthening of the current NACA liaison work with the Department of Defense and the Atomic Energy Commission. Although NACA has been working actively with both agencies on a wide variety of research areas and development projects it is likely that special liaison groups will be created by legislation to formalize this type of work.
- **Basic change** in Congressional relations. As part of the mixed independent offices appropriations bag, NACA has received minor attention and somewhat less than complete understanding from this sub-committee of the appropriations committees. This annual budget exercise has been the agency's only point of contact with Congress. Now Select Committees on Astronautics and Space Exploration are functioning in both House and Senate. Legislation has been proposed that



would establish a permanent joint committee along the lines of the committee handling Atomic Energy Commission affairs in Congress, but the two Houses may end up with separate permanent committees.

In tackling its new dual role in aeronautics and space technology the National Aeronautics and Space Agency is getting some clear mandates from Congress on how it wants the job tackled. These include:

• **Positive civilian control** of the national space research program. Congress is emphatic that both in its initial exploratory research phase and in ultimate development of useful space vehicles the civilian interests of the country get full consideration.

• **Freedom of scientific information** gathered in the course of the NASA program. This is a sharp reversal of the 1946 attitude of Congress in establishing a national atomic energy program when the strictest peacetime secrecy in the history of this country was written into the Atomic Energy Act. In that case, the U.S. was ahead in the field. Congress has stated that in astronautics, U.S. is clearly behind.

• **Sustained effort** over a long haul rather than initiation of "crash programs" in an attempt to re-establish our international prestige in space technology. Congress has indicated that it envisages a $500 million annual program for the next several years aimed at eventually reaching $1 billion annually and over-taking the Soviets in this field and maintaining superiority in space technology. These figures represent only the NASA effort and do not include Defense Department programs.

NACA was picked as the nucleus for the new space agency primarily because of its long record of successful research and development in the related areas of aeronautics and its existing manpower and facilities of which about 50% are already devoted to space technology. This will be the third time in its 43-year history that it has faced a fundamental change in the character of its operations forced by the technical trends of the times.

Although NASA will not be able to function officially until a bill is signed by the President, the present leadership of NACA has been working for some time on how to tackle the basic problems involved in transition to the new areas of activity.

One of the principal problems is getting and keeping scientific personnel of the required caliber in the new areas of NASA activity. It is certain that a deputy director will be added to the agency at a $21,500 salary. Provision has been made for 10 new top level posts at $21,000 annually and 250 new jobs at $19,000 annually. The director of NASA will be paid $22,500.

Under the director and his deputy there probably will be four assistant directors—one for aeronautics responsible for carrying out the presently planned NACA program in this area, and the other for astronautics with responsibility for expanding present NACA space technology programs and organization.

NASA plans to rely heavily on contract operations to expand its capabilities in required new fields rather than to attempt major expansion of its own facilities and staff. But it does face the problem of developing top-level staff in these new fields capable of directing the contract operations and organizing adequate programs. It also will have to develop a procurement capability far in excess of its present capacity, which is confined primarily to research facility construction and university contracts of relatively low dollar value in the basic research area.

Wallops Island probably will get the largest immediate facilities expansion program. NACA has been operating a series of rocket research vehicle test programs on this Virginia barrier beach for more than a decade but it is a very small facility in comparison to the new demands that will be made on NASA. It will be expanded to handle operation, instrumentation and data gathering techniques on space probes up to the size of the Atlas and Titan. NASA plans to use existing USAF facilities at Cape Canaveral, Fla. and the Pacific Missile Range facilities now under construction at Pt. Mugu and Camp Cooke, Calif. With a growing requirement for a satellite launching base close to the equator, it is likely that NASA will get the job of establishing and operating this facility, since its primary mission would be for research vehicles rather than military weapons.

Lewis Flight Propulsion Laboratory now is doing the bulk of its work on types of propulsion aimed at space applications and will require little change to become an integral part of the space technology program. Because of the proximity to the Wallops Island shooting site, NASA probably will build the bulk of any new space research facilities at Langley, Va., where it already has a large aeronautics research facility. NASA has no plans to build new facilities to extend its capability into the avionics field, where there is now a major requirement for its space research mission. It plans to use a contract operation to develop this capability similar to the Air Force use of the Lincoln Laboratory at Massachusetts Institute of Technology.

The NASA effort to organize a truly national space program with an acceleration aimed at surpassing the Soviet effort in five to ten years will involve use of all of the scattered and uncoordinated space technology facilities now existent in universities, research foundations, industry and military services. Currently its main problems will center around the Advanced Research Projects Agency, created in the post-Sputnik era last fall in an effort to get the Defense Department research program out of its technically timid atmosphere and co-ordinate the scattered efforts of the services on major new research programs.

Cooperation With ARPA

NACA and ARPA are working closely during the transition period before the final structure and scope of NASA is legally determined by Congress. As a matter of expediency, ARPA was given all of the Defense Department space technology programs to get them under way while debate over national space policy details was still raging. ARPA's present charter allows for its existence until next February when presumably some more permanent organization of the civil and military advanced research programs will be possible.

Among the other organizations NASA will be working with are the Army's organizations at Redstone Arsenal which may well change its basic character and become a space technology research facility under NASA's aegis; the Air Force Research and Development Command which has had a broad space technology program under way for several years; and the Office of Naval Research, which also has been active in the space field, particularly in bio-sciences, communications, upper air research and the Vanguard satellite program.

NACA has been working formally on space technology problems since 1952 when it officially initiated studies "of the problems associated with unmanned and manned flights at altitudes from 50 miles up and at speeds from Mach 10 to the velocity of escape from the earth's gravity." Late in 1957 it added a space technology committee to its working groups, encompassing the top men then active working in the space field.

The first project that is likely to come to fruition under the new NASA is a project begun six years ago under the directive quoted directly. It is the X-15 rocket powered research aircraft that is scheduled to take the first man on brief but scientifically significant trips through space next year. The X-15 program, like the supersonic research aircraft program that preceded it, is typical of the way NACA works with the military, science and industry on joint, technically co-ordinated research programs to probe the unknown areas of its fields. The X-15 was jointly financed by USAF, Navy and NACA with the contract to build the vehicle utilizing an experienced contractor—North American Aviation, Inc.

This X-15 research vehicle will be flown by company, military and NACA pilots in a carefully meshed program to extend the range of piloted vehicles beyond the bulk of the earth's atmosphere with an aircraft that still can perform usefully within the atmosphere envelope.

The next project on the space research list is a series of lunar exploratory probes aimed at providing data on the earth's moon and its surrounding territory. These lunar probe projects were initiated by ARPA at the direction of the President with the stipulation that they would be transferred whenever feasible to the new national space agency. ARPA now is managing this program through USAF's Ballistic Missile Division for the portion utilizing Douglas Thor missiles as the basic booster, and through the Army's Ballistic Missile Agency at Huntsville, Ala., for that portion using the Jupiter missile as its initial stage.

Behind the lunar probe program, also scheduled for initial operation next year, comes the man-in-space program, aimed at initial exploration of man's capability for functioning in various types of artificial environments and vehicles that can take him into space and bring him safely back to earth. USAF is carrying the main emphasis on this program at the moment but it is extremely likely that NASA will take over direction of this effort when it emerges from its organizational cocoon.

Coming along perhaps simultaneously with the man-in-space program will be the advanced satellites capable of performing tasks more technically sophisticated than the initial series of data gathering satellites sent aloft by the United States and the Soviet Union. These will include reconnaissance, communications relay and astronomical observations.

Even before the legislation creating NASA was drafted NACA had programmed its efforts so that by next year approximately half of its total resources would have been devoted to research in space technology including ballistic missiles, hypersonic glide vehicles, new methods of propulsion and new materials. Here is an indication of the areas mapped for exploration in space technology and some of the main problems within these areas and some of the new type of research facilities that have to be developed with them.

The main problems in aerodynamics and space mechanics are:

• **More fundamental** understanding of airflow characteristics and high temperature conditions occurring at hypersonic speeds encountered during re-entry.

SIMULATOR tests reaction to vertical, pitching accelerations at hypersonic speeds.

QUARTZ tube radiators simulate aerodynamic heating conditions on missile nose cone.

into the earth's atmosphere including physical and chemical changes in the air and the effects of these changes on the flow

- **Basic new data** on heat transfer and forces applied to ballistic missiles, hypersonic and space vehicles
- **Information on stability,** control and guidance requirements and methods of meeting these requirements for flight inside and outside the earth's atmosphere
- **Evolution of missile** and space vehicle configurations of various kinds compatible with propulsion and structural requirements and capable of performing useful military or scientific missions under all of the conditions on environment and speed imposed by the required flight plans

Virtually all types of NACA's existing research facilities are capable of being applied to various segments of these problems. For example, even the subsonic and transonic wind tunnels in addition to supersonic tunnels, are used on such problems as dynamic stability of missiles and space vehicles, fuzing of missile warheads during reentry into the atmosphere, the magnitude of hinge moments on gimbaled rockets used for control during powered flight, and landing characteristics of hypersonic aircraft.

NACA now has wind tunnel facilities providing test conditions up to Mach 20 (using helium) and temperatures in the test section up to 4,000F.

To get beyond the inherent limits of wind tunnels due to material limitations, NACA is developing other types of high-temperature apparatus to study the physical and chemical changes in the air at hypersonic speeds. Small arc jets from electric arcs are providing temperatures up to 15,000F but further technique development is required. The hypersonic ballistic range already has been developed to achieve simulated conditions at Mach 15 and a small atmospheric re-entry simulator is being used in which the model of a missile nose cone or space vehicle configuration is shot upstream into the special nozzle of a supersonic wind tunnel.

A larger re-entry simulator now under construction will provide conditions similar to those experienced by large, long range ballistic missiles satellites and space vehicles.

Research missile work at Wallops Island with fire stage rockets has resulted in test data up to Mach 16 by firing the last several rocket stages of the test vehicle downward. Work is under way to increase the speed of these simple, multi-stage research rockets to satellite and escape vehicle velocity in the near future.

Propulsion requirements for space vehicles are designed to:

- **Provide sufficient velocity** to overcome the earth's gravitational force. To do this thrust must exceed gross weight by a sufficient amount so that the energy consumed in overcoming gravitational force is not an excessive fraction of the total energy available. At the same time the thrust-weight ratio cannot be so high that final accelerations exceed allowable limits of the vehicle and its equipment.
- **Provide sufficient velocity** control both in magnitude and direction to permit a planned flight path in space. For this requirement both types of control must be available during the entire space mission, which may be measured in days or months. This is where ion propulsion with its relatively low thrust but extremely low rate of fuel consumption appears attractive.
- **Provide auxiliary power** required to operate auxiliary equipment, subsystems or other types of accessories. For this purpose the weight per unit of power must be extremely low and external fuel sources are attractive.

NACA research to meet problems in these areas involves new energy sources, either chemical, solar or nuclear; various types of working fluids, combustion products, lightweight gases, ions, plasma and photons; possible heat transfer fluids, either gaseous or liquid; mechanical devices to convert energy into thrust or power such as nuclear or chemical rockets, ion, plasma and photon jets; methods of controlling the powerplant, and the materials for powerplant construction and how they operate in the variety of environments to which they are exposed.

Most of NACA's research on structures and materials for missiles and space vehicles must be based on consideration of the load and stress conditions imposed through the wide variety of flight experience and utmost minimizing of weight in any given vehicle. Some of the goals of current NACA research in these fields are:

- **Establishment of the** interactions of heat, aerodynamic force, structural elasticity and inertia to avoid destructive vibration phenomena.
- **Evaluation of structural** configurations for various temperature ranges and composite arrangements that incorporate cooling, insulation, heat shields.
- **Determination of properties** and behavior of structures at high temperatures and transient heating.
- **Evaluation of the heat** resistant capabilities of materials and their applicability to space structures and missiles.
- **Development of new materials** with improved high temperature properties such as those required for atmospheric reentry at hypersonic speed.

Among the new research tools being developed in this area are: thermal structures tunnel that permits study of larger structural specimens at temperatures from -100F to +400F and at hypersonic speeds; hot air jet employing ceramic heat exchanges that operate up to +4000F are used on ballistic missile nose cone work. One of these jets soon will have a 5,000F hypersonic air stream 12 in. in dia. Other hot jets use rocket fuels to produce temperatures from 3,500 to 8,000F for studies of melting nose cones and ablation of various materials. ■

ARPA Shapes Military Space Research

Never in its uncertain history has U.S. military research and development experienced the budgetary upheavals and reversals of policy that have occurred in the past year.

Now, as the pendulum swings from last year's curtailment of effort to an increasing emphasis on all types of research and development, the unique new Advanced Research Projects Agency has been given a major responsibility for shaping policies and overseeing programs in space technology and other "upstream" areas.

In less than three months of operation, the three top men in ARPA—Director Roy W. Johnson, Chief Scientist Herbert York, and the deputy director, Rear Adm. John E. Clark—have taken their powerful mandate and apparently have created a workable situation by selling the Congress and the military on their philosophies and intentions.

Refreshing Approach

Most refreshing guideline laid down by ARPA so far is Dr. York's statement that "science cannot be tied to a specific objective, and if we are to have a military science to compete with what I believe is the defined Russian military science, we must be free to go down avenues of exploration without having a military weapon system objective predetermined."

ARPA's mission as prescribed by law is to cut across the traditional lines of the military services and fund and manage advanced research and development in the fields of intercontinental missile defense, military reconnaissance satellites, military applications of space technology and other advanced research and development that may be assigned.

The agency has the authority to make extensive use of the facilities of the military departments either by going through or around the service secretaries, to use other government laboratories and private industrial and university research groups and to establish its own facilities if necessary.

This broad authority gave rise to numerous fears in the Congress, the services and industry. These ran from concern that ARPA would be just another office to review and slow down research and development, to the darker prediction that the agency would try to centralize military research under one massive office and eventually try to control the thinking of all of the service laboratories.

However, ARPA's actual policy as outlined to the Congress has done much to allay these fears and has provoked favorable comment from many sources.

The major points of ARPA's policies and objectives were explained to the House Subcommittee on Defense Appropriations by Roy Johnson as follows:

ARPA is "in business to provide . . . expedited and forward-looking research programs which in the past have been retarded by the necessity for a formal military requirement. The fact must be recognized and squarely faced that if an end requirement, be it military or any other, must be established before we embark on research, then by definition it is no longer research.

It is our purpose to accelerate the national technological status by sponsoring research without having to prove an ultimate specific application before we embark . . ." Johnson said.

"This (is) not going to be an empire. For example there were two laboratories that were recommended for assignment to ARPA. They seemed to be quite obvious because they concerned themselves so much with outer space. We visited those laboratories. We found that they weren't laboratories in the sense that I had defined a laboratory and in the first three weeks we definitely came to the conclusion that this advice was wrong and that ARPA would not establish its own laboratories.

"We saw quickly," Johnson said, "that there was competence in the services, very high competence in their laboratories. We also quickly became familiar with the private laboratories and the laboratories that are a hundred percent supported by military funds . . . We felt that we could, by playing the field and going to a specific laboratory that had a specific capability, have flexibility.

"The thing that I am concerned

CRAB nebula in constellation of Taurus, photographed in red light by 200-in. telescope.

about in any laboratory that we could manage is that, as the character of the work changed, we would be forced to make work of a kind that might not be most productive."

Services 'Enthusiastic'

Johnson said the services so far have been enthusiastically supported this concept.

"I think that they were concerned in the beginning that we were going to finger certain laboratories and say to the Secretary of Defense, 'We want those transferred to ARPA.'

"I think they are no longer suspicious of ARPA's role in this connection. There are those in the services who have told me recently that they think ARPA has a real role to perform as a catalyst and synthesizer as well, but actually more important to prevent duplication and waste.

"There is duplication that is wasteful. I think that many times we ought to follow parallel courses toward an objective, but I think that duplication would be completely wrong."

Johnson believes that "ARPA can effectively carry out its responsibilities with a small staff of about twenty assistants together with the necessary clerical and stenographic support. In addition, . . . the Institute of Defense Analysis . . . (would) provide scientific and technical assistance with about 25 scientists."

IDA will serve as a contract agency for various skilled personnel to assist Dr. York.

These men probably will stay with ARPA from 12 to 18 months and their retainment through IDA will make it possible to pay them salaries that are more in line with pay in industry than most government salaries would be.

Congressmen Impressed

Johnson's testimony and that of the other ARPA leaders drew considerable praise from House Defense Appropriations Subcommittee members. They voiced the conviction that as presently conceived, ARPA would maintain and make use of the broad base of independent investigation taking place in U. S. laboratories, and would expedite the incorporation of new ideas into weapon systems policy.

Johnson and York's assurances that they intend to operate with a small staff, avoid directing programs solely toward specified military requirements and seek competence wherever it can be found, rather than creating some new facility, etc., were welcome news to many critics of past research and development policies.

But ARPA still does not have a completely free rein. By law, all its actions require prior approval from the White House.

While testimony before the appropriations subcommittee was very detailed concerning ARPA's relationship with the services and with other offices directly under the Secretary of Defense, it did not include the degree of agreement that ARPA had reached with the President's Scientific Advisory Committee under Dr. Killian or the fiscal authorities in the Office of the President.

ARPA will, of course, be required to follow the established pattern of justifying its present and projected expenditures each year to the White House, the Budget Bureau and the Congress.

Relations With NASA

Three existing and proposed government groups have functions closely related to ARPA's—the proposed National Aeronautics and Space Agency, Congress' Assistant Secretary of Defense for Research and Engineering and the Director of Guided Missiles in the Department of Defense.

The gray areas existing between these groups and ARPA and the present agreements that have been made to avoid overlapping action were explained to the House committee by Johnson.

ARPA is planning to turn over the Air Force and Army moon probes, the Naval Ordnance Test Station's mechanical scanner for moon probes and the remaining Army Explorer satellite shots to the National Aeronautics and Space Agency eventually. Seventy-two million dollars has been asked to fund this program. ARPA will administer it until the new civilian space agency is well underway.

Johnson said discussions still are going on between his office and the National Advisory Committee for Aeronautics to determine whether the man-in-space program and the development of 1- to 2-million pound thrust chemical rocket engines should be handled by civil or military agencies. Final disposition of any items of disagreement would be made by the White House.

Foote, Holaday Relationships

Assistant Secretary of Defense for Research and Engineering Paul Foote and Director of Guided Missiles William Holaday are both staff advisers to the Secretary of Defense Neil McElroy, while ARPA is a line agency of the department directed to carry out advanced research. Foote advises McElroy on all military research, development and engineering.

Foote's office and ARPA are to keep each other informed of their activities, and Foote can utilize the ARPA staff for technical and administrative reviews to the extent necessary.

The same relationship exists between ARPA and Holaday. Each is instructed to keep the other informed as to breakthroughs and advances.

Holaday also must furnish vehicles for ARPA's space exploration projects.

ARPA's has requested $520 million for fiscal 1959 and the specific point was made that this might not prove adequate if any program moves faster than anticipated.

Largest request is $157.4 million for ICBM defense. About $57 million has been committed for use by the Army in the Nike Zeus missile system. The remainder would be spent on experimental programs that might improve the Nike Zeus or the Air Force long range radar.

Johnson also testified that McElroy originally wanted ARPA to handle the whole anti-missile program. But Johnson said he felt this would put ARPA in the hardware business since Army already had the Nike Zeus past the research point.

Therefore, about $175 million of the anti-missile funding was placed under the Army's appropriations request to cover expenditures that clearly were not for research.

Fund Request

Air Force's fund request for its responsibility of providing long range early warning radar for the anti-missile program will $329 million. Total of the ARPA, Air Force and Army requests was over half a billion dollars for ICBM defense. Johnson also indicated that the feeling in the Department of Defense was that probably about $6 billion would be required to provide point defenses against long range ballistic missiles for the largest cities. More definite estimates could not be made, he said, until the results from this year's test programs are available.

York, discussing re-entry, said the re-entry problem had been greatly exaggerated. He said it has turned out that a dozen or so different design approaches could be used, and that 20 or 30 different materials would be adequate.

Next largest item on the ARPA program is $152 million for a military reconnaissance satellite. This refers to the WS-117L Pied Piper that Air Force has had under development for some time.

York said they would have a gross weight of 1 to 1½ tons and would be launched by an Atlas booster. A number of reconnaissance systems are being planned. The systems would operate for a month to several months depending on the percentage of the payload that could be devoted to batteries.

Orbiting altitude would depend on the useful life of the system. The shorter the time the reconnaissance apparatus would operate, the closer to the earth the orbit would be, and the apparatus could provide more detailed information.

Discussing the man-in-space projects still under study, York said: "The reason you have to send men there is because I do not believe it is possible to invent a piece of automatic machinery that can explore some place in the same sense that man can, and putting a man in orbit is just the first step." York feels that the man-in-space project fits into ARPA's responsibility very well.

"There is no well-defined requirement for a man in space today . . . and the reason that we cannot see these requirements, or spell them out in detail, I think is not because they do not exist, but just because we are not smart enough . . . to see what they are. So we are proposing and urging a man in space program on the grounds that we think it is reasonable to believe that there will be a military requirement sometime for a man in space."

ARPA also asked for about $15 million to be tentatively scheduled for the development of a very large liquid chemical rocket engine in about the one-to-two million pound thrust class. Five million dollars was also requested for research on smaller, high performance engines which would become second stage engines to top the million pound powerplants.

ARPA officials who testified before the House subcommittee received unusually strong praise from the committee members. Dr. York was singled out time and again for the clarity of his technical explanations.

Rep. Dan Flood (D.-Pa.) also warned the ARPA group about the "probable" result of the favorable reception they got from the committee. "Some of the fellows downtown who haven't been so well received up here will latch on to this and the word will be around that 'Johnson and York and these fellows are home free. We had better move in on that. We can hide behind this. They will, I know them. The place is crawling with crows down there, bureaucrats and military. If they think you are the white-haired boy, look out." ■

EARTH'S natural satellite as it appears at the age of 14 days through 100-in. telescope at Mt. Wilson-Palomar observatories.

USAF Space Effort Based on Research

The basis of the Air Force's strong position in the rapidly developing technology of space and the key to its strength in the future is its broad, varied program of research and development

Less than a year ago, all the services were de-emphasizing the importance of research for space because it was an unpopular subject in the Pentagon. Because of expenditure limits, USAF was in the midst of doing what its Assistant Secretary for Research and Development, Richard E. Horner, called "rather drastic things to our program . . . canceling large numbers of projects that were pending, reforming parts of the system and canceling other systems."

Since last Oct. 4 there has been a reversal in policies—political, strategic and fiscal—with regard to space technology. Although many have criticized the lack of speed and some have called for even greater reforms, an integrated national space program finally is being formulated.

Air Force and its partners in research and development—science and industry—are playing a major role.

But the latest changes in attitude and the integration of space efforts do not account for USAF's vitally important part so much as its previous years of research and development do.

The top priority ballistic missile program is the outstanding case of how past and current work are providing vehicles for tomorrow's thorough exploration of space.

ICBMs topped by other stages and in some cases boosted themselves by far more powerful engines, can take man as far as Mars until more efficient fission, fusion or ion engines have replaced them.

The X-15, a product of a 13-year USAF-Navy-National Advisory Committee for Aeronautics research aircraft program, will be the transition vehicle that precedes the manned orbiting capsule and the manned, globe-circling reconnaissance-bomber.

THOR will provide initial booster for lunar probes, other space exploration vehicles.

Although Soviet Russia's political-technical lead in astronautics will not be overcome for some time, the constant and rapid evolution that has been the most striking part of USAF's growth will contribute greatly to its efforts in this field.

Lt. Gen. John K. Gerhart, USAF's Deputy Chief of Staff for Plans and Programs, recently told a House Appropriations subcommittee:

"The Air Force . . . is not static. It is not immutable. . . . We are well aware of the need to venture, even to build out into the unknown. There are many examples of what receptivity to change has won for us.

"Our missile progress is one such example. And yet, it may be that this progress will ultimately realize its greatest value as a transition to the control of space.

"The Air Force's problem has been historically one of getting a platform above the ground and moving it from one place to another until it reached a destination where it could accomplish a military job.

"When we talk about space we are talking about projecting further these same essential functions of reconnaissance, offense and defense."

Earlier this year, Lt. Gen. Donald L. Putt, outgoing Deputy Chief of Staff for Development, told Congress what Air Force had done, what Russia was doing and what the U. S. must do now to win "the long, grim, difficult struggle" for control of space.

Most of the new programs or accelerations of existing programs recommended by Putt have been put into effect since and others will be.

ARPA-USAF Relations

The appearance of the Advanced Research Projects Agency on the scene and the creation of a civilian national space agency have modified Air Force's role in some of its own projects, but its background in these areas, the technical competence of the USAF science-industry team and the fact that USAF had vitally important space work already underway have assured it a major part of the national space program.

Coupled with top-level coordination and what appears to be a new determination in ARPA and in Air Force to divorce research from specific military requirements as much as possible, USAF's experience will become a key factor in what Putt called "the race of man into outer space."

Roy W. Johnson, Director of ARPA, recently told Congress his guess was that "more than half of ARPA's $520 million program would actually be executed by the U. S. Air Force."

Among the space programs still directly in the Air Force research and development budget or being carried out by it for ARPA are those listed below. Each is discussed in more detail elsewhere in this issue.

• **Pied Piper** reconnaissance satellite. Under study and initial development for 10 years by Air Force prime contractor Lockheed Aircraft Corp. and associated companies, the Advanced Reconnaissance System (WS-117L) has supported at $55 million in Fiscal 1958. USAF asked for $215 million for Fiscal 1959, but ARPA set $152 million as a "more proper" figure for the present.

• **Man-in-space.** Johnson said this program "would be Air Force, very substantially." ARPA's chief scientist Dr. Herbert York, said: "We are proposing and urging a man in space program on the grounds that we think it is reasonable to believe there will be a military requirement sometime for man in space, even though we cannot spell it out, and it is better to undertake these things, to have a deliberate program now, than it is to have a crash program later when the requirements can in detail be spelled out."

USAF has asked $170 million for a program that would put a man in orbit in 1959. ARPA asked Congress for only $46.2 million for man in space for Fiscal 1959, but left the way open to ask for more.

• **Lunar probes.** ARPA has ordered Air Research and Development Command's Ballistic Missile Division to fire three instrumented probes to the vicinity of the moon. In the case of Pied Piper, ARPA assigned the project to USAF and USAF and ARPA funds were merged. In the lunar project ARPA dealt directly with BMD. It did not transfer funds, but authorized BMD to cite ARPA funds for direct obligation and to administer the contracts. Direction of this project will move to the civilian space agency eventually, but BMD probably would continue to execute it.

• **Dyna-Soar.** Air Force has retained direct control of this family of manned, orbiting, boost-glide space vehicles primarily because it is based on stated military requirements. After five years of study the first project in the family is moving into the development stage.

• **X-15 research aircraft.** Still funded primarily by USAF, this North American rocket plane has become a model for the kind of service-civilian agency cooperation essential to a successful national space program.

• **Space medicine.** This work remains in the Air Force budget and contributes to almost all space efforts. It probably is the oldest space technology effort in the Air Force.

At the Pentagon level, USAF's space technology efforts are directly incoming Deputy Chief of Staff for Development Maj. Gen. Roscoe Wilson and his deputy for research and development, Brig. Gen. Homer A. Boushey.

ARDC's Support Role

At the operating level, the Air Research and Development Command under Lt. Gen. S. E. Anderson provides the foundation of technology through its nine centers and four allied locations (see map) and through more than 5,000 contracts with some 1,000 companies, universities and research institutions.

ARDC has grown from 38,000 in 1956 to about 43,500 men now, most of them engaged in contract management, evaluation, testing and inspection procedures and a limited number engaged in in-house research and development work.

The command has been plagued primarily by two problems:

• **Fluctuating** support of research and development since World War II.

• **Increasing demand** of day-to-day development and engineering problems, at the expense of real research and early development work.

On the first point, Assistant Secretary Horner told Congress:

"In the last 13 years, this country has gone through at least three full cycles of support of the military program. Immediately after World War II we demobilized. Our research and development program went to practically nothing.

"Over the period of the next few years we became gradually disenchanted with the Russians and we accelerated our research and development program until the late 1940's, at which time we went through an economy era and we took it apart again.

"The Korean war brought on another acceleration and, as of last Oct. 1, we were gradually in the process of taking our program apart again.

"Of all the things we do in the military departments, research and development is the most difficult to run on this kind of oscillatory support basis. It is almost impossible to imagine the havoc created in a research and development program by trying to rapidly reverse the level of support of the program.

"We are wasting millions of dollars through canceling programs, starting programs, accelerating programs, and slowing down programs.

"This, I am sure, is the major problem we have over a period of years in reaching our objectives in research and development in the military sciences."

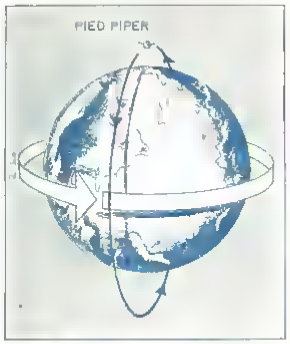
On the question of technical development and research, the part of ARDC's program which includes the fundamental work done to increase knowledge, incoming Assistant Deputy Chief of Staff for Development Maj. Gen. R. P. Swofford told Congress:

"The technical development and research effort is substantially constant for (the past few years). While it is essential that stability of funding be maintained in this fundamental area of our program, it is equally important that the level at which the stabilization occurs is high enough to assure that we get ahead and stay ahead in this period of rapidly advancing technology."

Funds requested (for Fiscal 1959) will permit achievement of the objectives established by the President's budget, but do not insure optimum progress in all-important fields of fundamental development and research.

USAF's total support of research and development in the upcoming fiscal year, including $1.394 billion from aircraft and missile procurement and support funds and $243 million from

ATLAS will play major role in space work.



construction and personnel funds will be $2 356 billion

ARDC's requested portion of this in actual research and development appropriations is $728 million In addition, $174 million in USAF money has been transferred to ARPA—$64.3 million of it from the R&D budget—and some of that will come back to USAF to carry out ARPA projects

For the purposes of management, ARDC breaks its programs down into three areas

• **Operational systems** $157 9 million About 60% of this is for work on strategic systems such as Atlas, Titan and Thor the B 70 bomber nuclear aircraft, etc This also includes air defense systems, tactical systems etc

• **Field operations and base support,** $332 9 million This covers operation of the nine major research, development and test centers and allied locations Increased testing, particularly of missiles, has increased this cost but the great bulk of test and engineering work is supported by production funds

• **Technical development and research** $228 2 million This vital part of the program accounts for only about 31% of the total research and development appropriation

A breakdown of this portion of the program into its three main components shows further how the research part of the spectrum at the far end from operational hardware suffers from the rapidity of technological advancement and necessity for attention to more immediate problems

• **Technical support** $35 million for research vehicles and the necessary test and instrumentation developments to make use of them Emphasis is on flight exploration at very high altitudes

• **Technical development,** $153 1 million This covers tasks such as rocket propulsion nuclear warfare, fighter fire control, in 34 areas in which the resulting developments can be expected to apply to military missions

• **Research,** $40 1 million These are projects of a fundamental nature closely allied to basic research in the fields of propulsion, materials, electronics, geophysics, biosciences and aeromechanics

Although this basic research category has increased $3 7 million over last year it amounts to only 13 06% of the research and development appropriation itself and less than 1% of the $2 356 billion requested for R&D from all Air Force appropriations An estimated 200 to 300 of the command's 43,500 complement are engaged in basic research

ARDC's Air Force Office of Scientific Research in Washington, D C., and its European Office in Brussels, Belgium support most of the basic research effort through contracts While AFOSR is the major center for this, Wright Air Development Center, Rome Air Development Center, Air Force Cambridge Research Center and others carry some basic work in house and on contract

A staff of 40 in Brussels monitors some 180 contracts in 16 European and Middle Eastern countries About 130 of them are in basic work Contract level is about $3 million

Other centers and their basic research development and test missions

• **Cambridge Research Center** Geophysics and electronics primarily airborne

• **Rome Air Development Center** Electronics primarily ground based

• **Wright Air Development Center.** Materials, propulsion, secondary power, aerodynamics, human factors, navigation, guidance, reconnaissance, bombing, fire control etc

• **Arnold Engineering Development Center** Aerodynamic test and simulated altitude propulsion test for USAF, contractors and other services

• **Air Proving Ground Center** Systems engineering tests and operational evaluation tests and development of nonnuclear weapons

• **Missile Test Center** Long range missile test and evaluation for USAF, contractors and other services and training

• **Special Weapons Center** Nuclear weapons and their effects and test support to Atomic Energy Commission

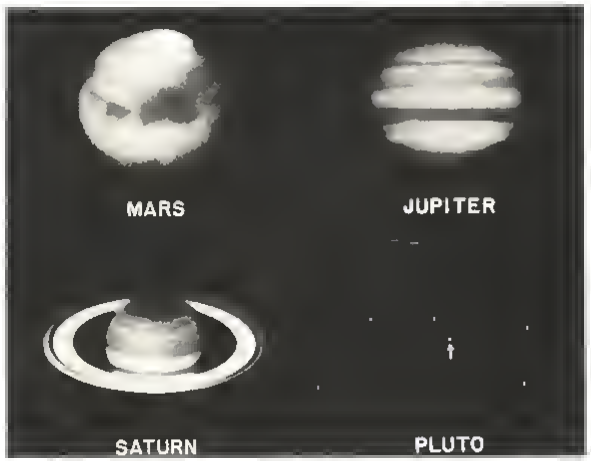
• **Missile Development Center** Short range missile test guidance subsystems test, biodynamics test

• **Flight Test Center** Aircraft and rocket engine test and evaluation for USAF, contractors other services

While the command provides a strong technological base to support USAF's missions, the problems of growing from a force made up solely of manned aircraft to the proper balance of aircraft and missiles to the triple mixture of aircraft, missiles and spacecraft in a very few years have imposed tremendous burdens on the research and development program in an extremely competitive situation

Gen Swofford told Congress

"I am no expert on the Soviet Union's research and development program We do see evidences of what they are able to accomplish There is certainly nothing that makes us feel very good about the rapidity with which we are overcoming these basic trends of them catching up to us, or possibly surpassing us" ■



PLUTO as photographed by 200-in telescope and Mars Jupiter Saturn by 100 in.

Navy Moves to Establish Space Mission

Navy is moving quietly but effectively to establish itself in space both politically and technologically

Politically, the Navy is making no sweeping attempt to grab all or most of space as its private domain What it does hope to do is convince the Defense Department, White House and Congress that it has a logical need to go to space in order to carry out present mission assignments

Rear Adm John T Hayward, Assistant Chief of Naval Operations for Research and Development, recently told the House Select Committee on Astronautics

"There has emerged an implication in certain areas that the Navy is not interested in a space or satellite program This is absolutely untrue The Navy definitely is interested in, and desires active participation in, a national satellite and space program"

Man-in-Space Wanted

The space needs already listed publicly by the Navy include reconnaissance, communications relay and navigation aids In addition, Navy is pressing for Defense Department permission to place a manned weapon into space

A small group within Bureau of Aeronautics has been working for more than a year on definite plans for a man-in-space project, and BuAer last month asked the Advanced Research Projects Agency for approval of a specific program (AW May 26, p 31) As outlined to ARPA, prime contractors in the program would be Goodyear and the Martin Co Navy estimated the cost of getting the project under way at $600 000 Similar more-advanced projects also are being studied

All the BuAer man-in-space programs are primarily weapon systems and each envisions use of the sea as the vehicle's home base Early systems would be based on the surface of the sea, but eventually Navy hopes to go underwater, with a manned space weapon system patterned along the same general lines as the Polaris submarine concept

Navy argues that water basing—particularly that incorporating mobile underwater systems that could hide for long periods beneath the polar ice caps—would provide an elusive target and an ever present threat

In addition, its spokesmen say, vehicles designed for water landings would have the advantage over land based systems of having broad stretches in which to land in the event of a navigational error on the part of the crewman or ground controllers attempting to return the craft to a pre-determined point on the earth's surface

Several such contracts to bear out its findings have been let by Navy, and some already have been completed In its studies of manned vehicles, a Bureau of Aeronautics spokesman says,

"We've limited ourselves strictly to military applications, with no attempts at publicity stunts involved"

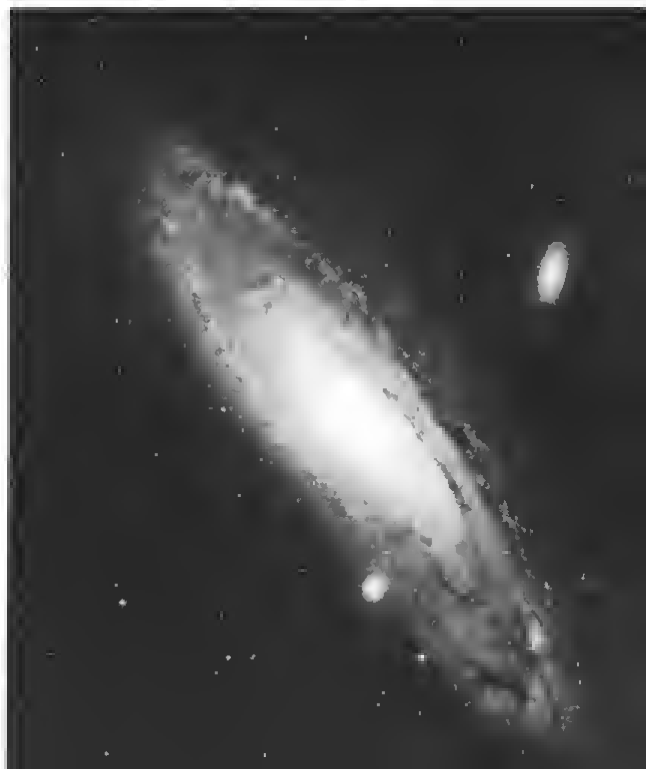
The vehicle itself would be all Navy, but an outside service probably would be called upon to provide the necessary propulsion system Initial discussions have been conducted with the Army regarding possible use of the Jupiter C intermediate range ballistic missile which will be available for other than pure missile uses much sooner than the solid-propellant Polaris fleet ballistic missile

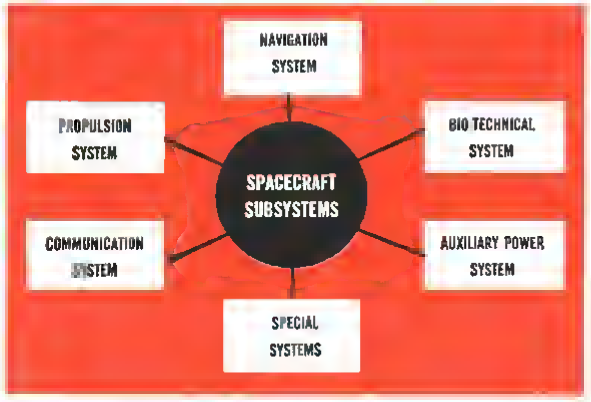
Regarding the present controversy as to whether man would be useful in space or whether an unmanned machine could handle the job more efficiently (AW May 5, p 26), Navy believes there is a vital role to be played by the human crew member One official explains:

"In an unmanned satellite the question of processing the data received becomes a monumental task If man could be used to take in 95% of the information and the machine only 5%, this problem would be reduced considerably He also can exercise judgment in selecting targets This means, if you're going to ask him to delineate problems, you have to give him a means of changing profile, so it will be a different type vehicle than the unmanned system Additionally, there is the question of security Man can store the information and bring it back to earth with him"

Technologically, the Navy believes it has a wide range of experience and knowhow to offer for space programs of its own and those of other services. It began research and development

GREAT NEBULA in Andromeda taken with 48 in. telescope





studies and experimental developments related to space travel in 1942. By 1945 it had come up with a firm proposal for a satellite project. After lengthy debate, the proposal was rejected by the Committee on Guided Missiles of the Research and Development Board as not having sufficient military value.

Navy's medical programs also pioneered in human factors research designed to keep man alive and operative in space. Naval Research Laboratory has gained experience in establishing telemetering stations and in recording and processing data received from the U.S. and Soviet satellites fired to date. Such experience, Navy feels, will be particularly useful in the more advanced systems to come, when the ground stations also will exercise at least some control over the profile and mission of both manned and unmanned vehicles.

Another area in which the Navy has figured prominently since 1946 is the field of high altitude research. Balloon flights sponsored by the Office of Naval Research have carried men and instruments to altitudes of up to 86,000 ft. The program includes extensive plans for sending large telescopes to altitude. ONR hopes to eventually place a large telescope into orbit.

Naval Research Laboratory has sponsored an upper atmosphere rocket research program over the past several years, beginning with the Martin Viking at the end of World War II. One Navy developed rocket, Aerojet's Aerobee Hi, reached an altitude of 193 mi., and Navy's experience in upper atmosphere research in general was a major factor in its selection as manager of the Vanguard earth satellite program.

Navy spokesmen also point out that they can supply to a national program strategically placed ships properly instrumented and equipped to perform such essential functions as mobile launching, tracking, data collection and analysis, control and recovery. Telemetry ships would permit the range to be altered or extended to monitor and track vehicles placed in various orbits.

Such ships may become an integral part of the Navy-managed Pacific Missile Range now being instrumented. Scheduled to become partially operational for limited intermediate and intercontinental firings by October, the range when completed will cost an estimated $158 million. Funds for the range in the Fiscal 1959 budget request total $34.1 million including $23 million for instrumentation and $4.6 million for test firings.

Along with telemetry, the Naval Research Laboratory has worked extensively in the fields of instrumentation and communications. One NRL spokesman—referring particularly to the experience gained through the Vanguard earth satellite program—says "Anybody working in these fields (instrumentation and communications) who doesn't consult us isn't properly up on the state of the art."

Whether the political or technological roadblocks will provide the greater obstacle for Navy's plans for a broad-base space program within the near future is still largely unanswerable.

Drafting of the nation's over-all space program beyond the International Geophysical Year, the direction it will take and the roles and missions of the various services is awaiting final organization of the civilian National Aeronautics and Space Agency, and some delineation of its responsibilities as opposed to those of Defense Department's Advanced Research Projects Agency.

However, Navy has firm programs on hand and is prepared to move rapidly once a go-ahead is received, whether it be received from ARPA or NASA.

As it now stands organizationally, Bureau of Aeronautics will concern itself solely with man-in-space programs. Bureau of Ordnance will most likely become the lead bureau for the large unmanned systems, particularly reconnaissance vehicles and systems employing the solid-propellant Polaris as part of its propulsion system. Office of Naval Research under Chief of Naval Research Rear Adm. Rawson Bennett and the Naval Research Laboratory, will provide much of the scientific backup for all the Navy programs.

The Naval Observatory also is expected to play a major role in both the Navy and the over-all national space programs, particularly in the fields of telemetry and the interpretation and dissemination of data from navigation satellites.

Navy believes that unmanned vehicles for reconnaissance, communications relay and navigation can materially benefit its mission on the sea.

Uses for Satellites

A navigation satellite, for example, could provide the commander of a Polaris submarine information as to his exact location at sea, a fact he must have if he is to fire his missile at a specified target with any hope of accuracy. A reconnaissance satellite might provide him with target information on one orbit around the earth, data as to how successful his firing was on another. Communications satellites would be of obvious benefit to all the Navy forces.

If money and permission are received, Navy might also send up satellites instrumented to study the nature of the sea itself. Results of such a study might provide information that would prove invaluable in the development of improved systems for anti-submarine warfare, an area in which the Navy critically needs improved equipment.

Much of the over-all responsibility for presenting the Navy's case and then monitoring whatever programs accrue will lie with Adm. Hayward in his role as Assistant Chief of Naval Operations for Research and Development.

Adm. Hayward heading an office that is still less than a year old acts as the principal adviser to the Chief of Naval Operations in the areas of research and development. His functions include approval of operational requirements proposed by the warfare divisions in the office of the Chief of Naval Operations. He also reviews the technical development plans that the bureaus propose in response to these requirements.

It will be Hayward's office that will make the major recommendations as to which bureau will handle what in the Navy's space program. Essentially, his office is divided into two main branches—weapon (support) system planning and program management, including operational evaluation. ■

Army's Mission in Space Is Expanding

Army, which put the first U.S. satellite into orbit, has been authorized by Advanced Research Projects Agency to undertake one, and possibly two, lunar probes and also to launch two, and possibly three, earth satellites. The satellites will be Explorers or variations thereof and the rockets used will be modified Jupiter-Cs.

The Army's proposal to place a man in a capsule atop the Redstone missile and send him up to an altitude of 150 mi. is still under consideration by the Defense Department. But this experiment is not tied in with the Army's space work, declares Maj. Gen. John Medaris, Chief of Army Ordnance Missile Command. Rather, it will be part of a separate series of experiments concerned with transporting men by missile—not through space, but from one point on earth to another.

This "men-by-missile" program would be more closely associated with special forces operations. The idea is to get a small number of specialists such as a medical aid or demolition team to a key point at a specific time "with the assurance that they won't be clobbered by the enemy on the way in."

Separation Impossible

Actually, it is impossible to separate missile or weapons work from space projects, Gen. Medaris declares. Technical problems for both are closely interlocked, there are many fruitful opportunities for cross-pollination of ideas, variety makes the work of the researchers more challenging.

Army has no intention of trying to keep space and weapons projects distinct, either in its own facilities or among outside contractors. The recent placement of the Pershing contract with the Martin Co., contrary to some speculation, does not signify any change in the Army's arsenal concept nor is it part of any plan to give weapons work to private industry in order to keep Army scientists free for space work, says Gen. Medaris. As an ordnance manager, he is interested in maintaining a reasonable workload balance between industry and government. At present, the balance in the Army's missile work runs about 70% to industry and about 30% in-house. The average division is closer to 82% for industry to 18% in-house.

Right now, the Army is running about 80 static firings a month at Redstone Arsenal. Most of these are part of weapons programs. Space programs constitute only a very small percentage of current work. From here on in, Gen. Medaris expects to see an increase in both the over-all missile work and the percentage represented by space projects.

To better handle its rapidly expanding missile work, the Army recently reorganized its Redstone Arsenal complex. Effective Mar. 31, 1958, the Army Ordnance Missile Command came into being after about 15 months in the gestation period.

The creation of this new command (see chart, p. 92) is designed to enable the Army to exploit its missile capabilities as fast and as fully as possible by placing all the resources in this area under one commander along with the responsibility for all the decision-making required to bring a missile from an idea to a field-proven weapons system.

This new command extends from California to Cape Canaveral, Fla. with the management headquartered in Huntsville, Ala. Commanding general of AOMC, Gen. Medaris, reports directly to the Chief of Ordnance on routine research and development projects. For special priority—weapons or space projects, there are direct access lines between Medaris on one end and, on the other, the Secretary of the Army, the Army Missile Committee, and the Advanced Research Projects Agency.

Under Medaris and his command headquarters staff come Redstone Arsenal, Army Ballistic Missile Agency, Army Rocket and Guided Missile Agency, White Sands Proving Ground, and Jet Propulsion Laboratory.

Non-Ballistic Responsibility

ARGMA, which is the new group, has taken over the responsibility for non-ballistic weapons formerly held by Redstone Arsenal. These weapons include Sergeant, Corporal, Honest John, Little John, Nike Ajax, Nike Hercules, Nike Zeus, Lacrosse, land-based Talos, Dart, Plato and Hawk. At present, ARGMA, which is under the command of Brig. Gen. John G. Shinkle, has the largest budget of all AOMC subgroups. In 1959, for example, ARGMA will spend approximately $180 million on research and development and perhaps another $800 million on production and procurement.

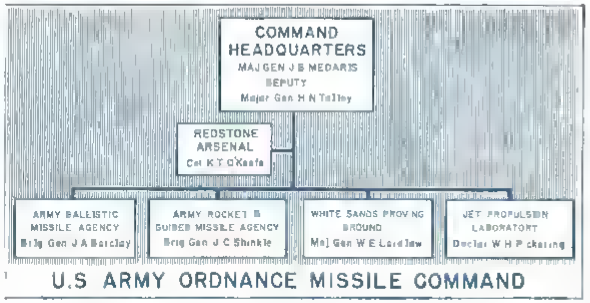
Redstone Arsenal, the physical home base of AOMC, is now essentially a post command. Under the direction of Col. Keith T. O'Keefe, it is responsible for the housekeeping of the 40,000-acre arsenal reservation and for providing support to ARGMA, ABMA and the Ordnance Guided Missile School. Besides OGMS, other tenants on the base who are not part of the AOMC table of organization are Rohm & Haas and Thiokol, which do work on solid propellants for ARGMA. Combined support for all AOMC groups will cost about $137 million next year.

White Sands

White Sands Proving Ground, commanded by Maj. Gen. W. F. Lindlaw, is located in south central New Mexico. Its main mission is providing integrated range facilities for flight testing of missiles under development by all three services. In addition, it conducts laboratory tests of Army missile components and carries out independent engineered testing of complete Army missile systems before they are released for field use. AOMC estimates White Sands will spend $70 million next year.

Jet Propulsion Laboratory, located

JUPITER-C, carrying Explorer, takes off from Cape Canaveral, Fla.



near Pasadena, Calif. is a government-owned, research and development facility operated for the Army by California Institute of Technology. Director of the laboratory is Dr. William H. Pickering.

JPL is responsible for originating, developing and testing new guided missiles, doing basic research in the physical sciences in support of weapon system development and making feasibility and evaluation studies of special programs of national interest. Next year JPL will spend $25 million carrying out its missions. It will make use of test facilities at Edwards AFB, Patrick AFB and White Sands in addition to its own near Pasadena which include two supersonic wind tunnels and a new hypersonic tunnel now nearing completion.

Importance Grows

Among other things, the laboratory was responsible for the development of the Corporal, the scaled-down Sergeant engines used in the Jupiter C, and for the design of the Explorer. Currently, it is charged with the development of the Sergeant missile and is involved in the continuation of the Explorer program and in other Army space projects. JPL has a library containing 150,000 volumes on jet propulsion and related missile subjects, it is believed to be the most complete collection in the field.

The Army Ballistic Missile Agency was created on February 1, 1956 to expedite the development of the Army's ballistic missiles—a project that was becoming big and important enough to separate from the rest of the missiles—which were under the jurisdiction of Redstone Arsenal. It was built around the original Redstone development team, which consisted of Wernher von Braun and some of his fellow German scientists who developed the V-2 at Peenemunde, and was assigned responsibility for both the Redstone and Jupiter missiles.

ABMA still holds the responsibility for these weapons, as well as for all space systems based on these missiles, such as the Jupiter C.

In addition, the Army has placed the development of the new Pershing ballistic missile under the aegis of this agency.

ABMA Spending

Brig. Gen. John A. Barclay, who had been Deputy Commander of ABMA under Medaris, became commander when Medaris moved up to AOMC. The Air Force, which will operate the Jupiter, has a liaison office attached to the agency and its 864th Jupiter Missile Squadron in training there. Dr. von Braun directs the Development Operations Division which consists of 10 laboratories and constitutes the largest segment of ABMA. Of the more than $650 million ABMA is scheduled to spend next year, over $95 million will go into research and development, the rest, into production and procurement.

In all, the recently created Army Ordnance Missile Command under the direction of General Medaris, will spend over $2 billion during Fiscal 1959.

It has the responsibility for 15 major weapon systems and a still undetermined number of space projects. It employs 23,000 people (including 5,000 military personnel) and directly influences the activities of another 9,000 military men, occupies over 25 million acres and operates facilities worth close to $500 million, not including construction underway and future construction planned.

Experienced Group

"We have the only rocket group in the country here that has 20 years experience as a team. And we've had to pay for only 10 years; Germany paid the rest."

The colonel who made this statement was referring, of course, to ABMA's Development Operations Division staff under von Braun.

It is this group that will carry the biggest share of the Army's space and satellite program. According to Medaris, his first orders from the Advanced Projects Research Agency assured him that the talents and abilities of ABMA will be well utilized in the space program. Jet Propulsion Laboratory will continue to work on space projects and, with ABMA, will make up AOMC's space team. Both groups, of course, will continue their work on weapon systems as well.

Although some details still have to be worked out and others are subject to change, the development of future Army space projects will probably progress as follows:

First comes the idea. This may originate anywhere, but more than likely will come from one of the researchers within JPL or ABMA's Development Operations Division. From the originator, the idea will go to other researchers who will build up on the basic concept, answering questions such as: What will it look like? What will it cost? When can it be ready? What will it accomplish?

The concept will then proceed to AOMC Headquarters staff. Here, the research and development group will go over the project and pass it on to General Medaris. At this point, Medaris may consult with his chief scientist, Dr. Clifford G. Quarles.

Special Proposals

If the proposal in question is a satellite or some other device considered of special significance, Medaris will forward it directly to ARPA, with copies going to bypassed groups in the table of organization. Otherwise, the project will proceed to the Chief of Ordnance who will decide what effects it will have on other development programs, both space and weapons.

From Chief of Ordnance, project passes to Chief of Research and Development whose office is actually part of Secretary of Army's staff. R&D, which is generally notified at the beginning of a project, recommends it to the Chief of Staff and the Defense Department as having official Army approval, and the proposal moves on to ARPA.

If it approves the project, ARPA authorizes AOMC to start work and provides the necessary funds. Periodic progress reports by AOMC keep ARPA informed on the development of the program.

In the event the program originates with ARPA, it is submitted to the Army, Navy and Air Force for bids. In the case of the Army, it would go directly to Medaris. Medaris would call in ABMA and JPL and ask them to prepare a detailed bid giving costs, schedules, etc., which he would then submit to ARPA for approval and authorization. ■

Industry Faces Stiff Space Age Rivalry

Tougher competition for more dollars providing fewer end items apparently will be industry's pattern for the future.

As Defense Department and the state of the art push further into space, there will be fewer prime production contracts, each representing a large dollar volume, plus an increased demand for basic research and development.

The move toward fewer prime contracts requiring diverse talents and capabilities is expected to push the larger firms gradually into a number of loose associations formed to bid on specific projects and disbanded when the programs are completed or the contracts are lost to another group of contractors. Within the association, each company would carry part of the load of a particular contract and one firm would act as the over-all manager.

Dyna-Soar Is Exemple

The trend already has begun with the team proposals for development of the Dyna-Soar hypersonic glider project.

Technological capability, funds and facilities necessary for the development of end items related to space, and the probability that the company associations will be capable of performing most of the associated work with a minimum of subcontracts, may cripple some of the smaller firms now engaged in production. Others with particular skills needed by larger firms may be absorbed or merged. Still others will evolve into essentially research and development firms.

Some industry spokesmen believe that the move toward loose associations of contractors could provide more security for the firms involved than they have now. One company, they say, might be involved in several associations working on a number of prime contracts. Cancellation of one large contract would affect a number of companies but in a relatively small way, rather than driving one particular firm to the wall, as can happen under the present system.

Just how great a change the space era will bring to the over-all structure of industry will not be resolved until the Defense Department and Congress determine how fast, and in what directions the U.S. effort will be pushed.

Both industry and military officials generally agree, however, that there will be no overnight transformation. Shift in the defense dollar from conventional systems to space vehicles and the consequent changes within industry will be gradual, generally following the pattern established when the ballistic missile appeared as a complement to manned aircraft.

One change predicted by Malcolm A. MacIntyre, Under Secretary of the Air Force, and Dudley Sharp, Assistant USAF Secretary for Materiel, will be the emergence of avionic and powerplant manufacturers as heads of weapon system contracting teams. MacIntyre adds:

This is not a prediction. It is simply a recognition of the fact that evolutionary processes are at work in industry as well as in military technology.

In a speech at a recent meeting of the Society of Automotive Engineers in New York in which he outlined what the Air Force expects from industry, MacIntyre also warned that industry research and development programs will be expected to provide giant step advances in performance. With first article weapons costing multimillions per copy, we have no room for programs which promise but slight improvements over present systems.

Industry, he said, must develop new production techniques to increase the efficiency and accuracy of production and "critically" take inventory of its facilities in order to phase out tools, high bay areas and warehouses in excess of present or planned production.

"Lower production quotas," he said, "will directly affect the overhead we must load onto unit costs. Therefore it is an urgent necessity that we take every effort to hold overhead to a minimum. Excess overhead could well mean cutting the quantities to be produced." MacIntyre added:

At the management level, companies should evaluate their financial management and financial controls so that they may have better expenditure control.

In the area of personnel, management must make full use of its labor force, and particularly the utmost use of the technical skills of its engineering people.

Tight Fiscal Policies

The government also can be expected to continue the policy, which it began to push seriously during the financial crisis of early Fiscal 1958, of insisting that industry provide more and more efficiency and accuracy of production and "critically" take inventory of its facilities in order to phase out tools, high bay areas and warehouses in excess of present or planned production.

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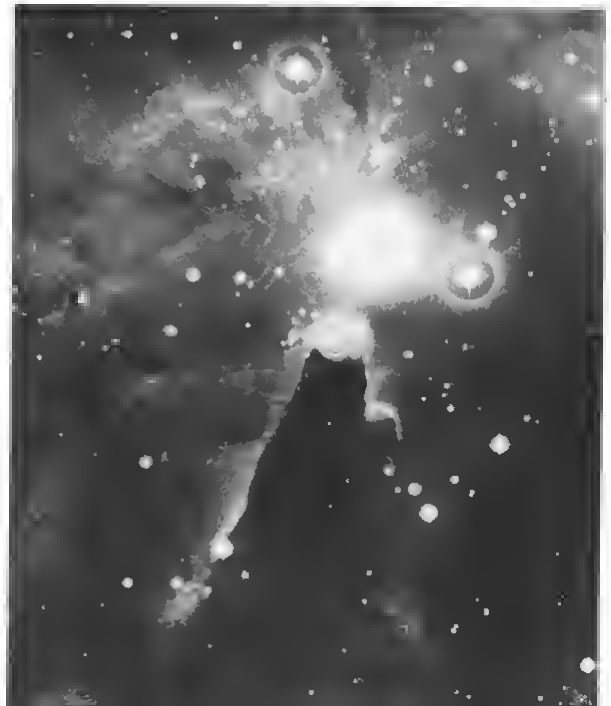
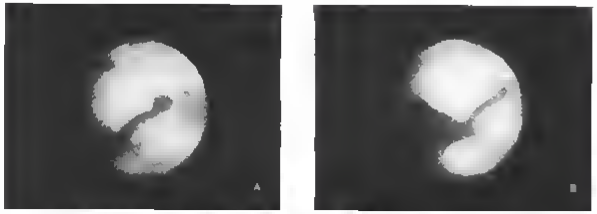
NEBULOSITY in Monoceros as photographed in red light by 200-in. telescope.





VIEWS of planet Mars, taken in red light, show rotation.

of its own funds to support basic research programs and the new types of facilities needed for the development and production of advanced weapon systems.

Stringent Defense Department expenditure targets forcing stretchouts in progress payments, slippages in delivery schedules and requests for deferred billings (AW Apr 21, p. 26) also are expected to remain in the picture for some time to come.

Burdens that the present fiscal policies impose on industry, slowing the development of advanced systems were outlined by Ernest F. Leathem, assistant to the president, Raytheon Manufacturing Co., at an industry-Navy research and development conference.

Low Rate of Return

The policies as outlined by Leathem produce results almost directly counter to those MacIntyre says the Air Force expects. Commenting upon the relatively low rate of return paid by the Defense Department for research and development work, Leathem said:

"Another serious question is how government can expect industry, at such low rates of return, to finance and expand its research and development facilities or even to keep them modern.

"Certainly in times of tight money and higher interest costs, lenders will prefer loans to businesses earning at, or better than, the national average, not ones at less than half of this amount. The same is equally true of investors in equity stocks.

"Depreciation allowances, even as recently liberalized, only allow recovery of initial cost—not replacement value of today's market. Obsolescence takes a greater and greater toll as the pace of technological advances accelerates.

"Therefore, moneys accumulated through such reserves are not sufficient to meet their purpose, putting a still further drain upon profits and creating a still larger requirement for working capital.

"The only way industry engaged in government work—and especially in research and development projects—can meet these conditions is to find a way to earn higher rates of profit on such work. The only alternative is more government subsidization which would appear to be both contrary to our basic concepts of private enterprise and impossible under the present shortage of government funds."

Bankers' Views

Leathem's remarks are underscored by a report on the aviation industry compiled by the Aviation Securities Committee of the Investment Bankers Association of America. The report said, in part:

"While free competition in the investment market has reduced aircraft manufacturers to a low priority for new capital investment, the need for such investment in terms of national survival may be greater than at any time in history.

"The aircraft manufacturers' problem is in large measure a financial problem. The solution lies in a congressional appropriation policy and a Defense Department procurement policy that will afford the aircraft manufacturers adequate stability, allowing them to successfully compete in the free capital markets for additional investment in their high risk industry. In this sense, adequacy must be determined—not by an arbitrary formula or by administrative decree—but by a growth and stability factor that will attract the required capital to ensure American aviation superiority."

Whether or not the financial spigots are opened—and this can only be done through the politically explosive expedient of raising the national debt ceiling—the Defense Department, and Air Force in particular, are approaching space on two broad fronts: unmanned satellites and manned vehicles.

Space System Approaches

In the move toward space, Secretary MacIntyre says a "considerable amount of research and development effort will be directed toward the solution of many system problems.

"Among these are such areas of interest as flight control and guidance systems and extremely long-range communications. Much effort must be devoted to developing vastly improved propulsion systems . . . And of course materials engineers and scientists will be engaged in developing alloys, ceramics and cermets for space vehicles. . . .

"A greater proportion of our hardware dollars will be used to buy specialized items in quantities of two to five copies per type. This, in turn, will further reduce our need for mass production facilities and for quantity output tooling. The ratio of engineering manhours to labor man hours will alter considerably, in favor of the former."

Industry, in turn—and, again, with the direction in which the nation will launch its major effort still in doubt—has flooded Defense Department and individual services with proposals for manned and unmanned space flights and plans for various lunar probes and orbits.

Air Force and Army already have been given the go-ahead on lunar probe programs, and USAF is developing an unmanned reconnaissance satellite with Lockheed Aircraft Corp. as prime contractor. Other industry proposals that have been presented include:

- **Dyna-Soar** hypersonic glider project.
- **Plan to add a Navaho booster** to North American's X-15 high-altitude research aircraft in order to obtain a minimum orbit within a minimum time span.
- **Aeronutronic Systems Inc.'s plan for** a Phase II follow-up of Project Farside that would place a rocket in the vicinity of the moon at an estimated cost of $3 million.
- **Aerobee M, a moon orbit** proposal by Aerojet-General Corp., a five-stage solid propellant vehicle based on Aerojet's Senior rockets which were developed in connection with Navy's Polaris fleet ballistic missile program.
- **Convair proposal for a four-man** space station, which the company says could be put into a 400-mi. orbit within five years at a cost of approximately $500 million. Designed by Krafft Ehricke, technical director of Convair's Astronautics Division, the station concept is based on the Atlas intercontinental ballistic missile.

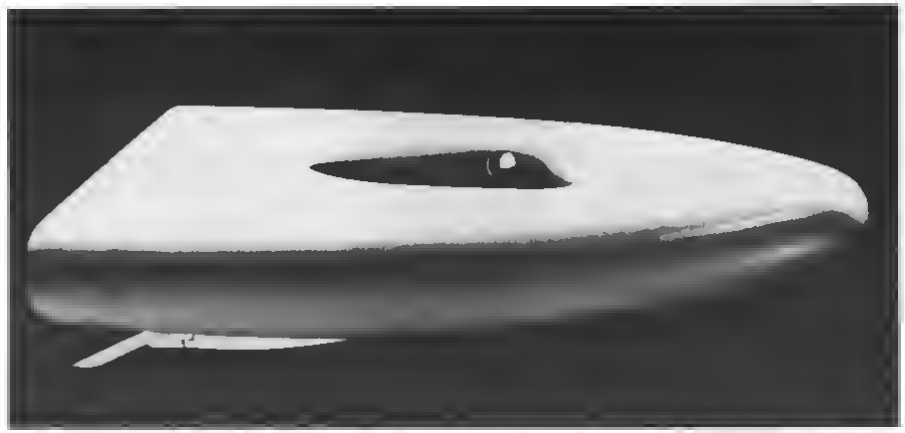
One factor that could be of major importance to industry in the future, and help ease its economic burden, is the tentative step Army has taken toward modification of its arsenal concept (AW March 31, p. 19).

In a first step toward relying more heavily upon industry, Army awarded the Martin Co. a multi-million dollar contract for research, development, testing and production of the 500-700 mi. Pershing solid propellant missile.

Army spokesmen concede that the Pershing contract approaches a test case for industry and that the degree to which it will modify the arsenal concept depends largely upon the success of the program. ■

NORTH AMERICAN pilot Scott Crossfield wears MC-2 suit in heat test at Wright Air Development Center.

Man in Space



MOTORBOAT satellite designed by National Advisory Committee for Aeronautics gains lift from shape, re-enters slowly, lands on water.

Man-In-Space Timetable Still Debated

By Irving Stone

Air Force's Man In Space-Soonest (MISS) program, scheduled to put a manned capsule satellite into a 200-mi. orbit by the end of next year, is considered too daring a project by some scientists and engineers close to the space technology picture.

Time scale for the MISS project (AW Apr. 7, p. 26) does not permit solution of prime problems to ensure a successful mission and safe return, they say. They point to the great number of human factors problems which must be solved first and add a final caution—that the "reliability" of the manned orbiting vehicle should approach that of present-day conventional aircraft.

Air Force planners aware of these contentions probably are pushing for relatively early manned satellite trials because they feel:

- **Many human factors** aspects of space travel never will be resolved adequately in ground-based laboratory environment.
- **Manned space vehicles,** regardless of type, will not achieve the operational reliability of present-day aircraft for a long time to come. The new and relatively hostile environment of outer space will make achievement of this reliability infinitely more difficult than that attained in 50 some years of progress from the first powered, heavier-than-air flight to present supersonic aircraft.
- **Man will never** be "fully" ready to cope with all the progressions of space travel and he will have to begin fitting into these successive stages by early and reasonable participation, with all its risks.
- **Propaganda value** of putting a manned satellite into orbit and recovering it would be of tremendous value to U. S. international prestige and would set the pace for support of military and scientific projects, which are so closely interrelated in the new space era.
- **USSR's** successful orbiting of the dog-carrying Sputnik II indicates that Soviets probably are not far from attempting earth-orbiting satellites.

Dozen Preliminary Shoots

Scientists and engineers who feel that Air Force is projecting the MISS program on too accelerated a basis also point out that the program will have to start almost from scratch, will require about $170 million in initial funding, will involve at least a dozen preliminary shoots with animal-carrying satellites—some of them recoverable, perhaps, to check after-effects of environment and re-entry on living subjects. They suggest the joint Air Force-Navy-National Advisory Committee for Aeronautics-North American Aviation Inc. X-15 project as an alternative, with its logical, step-by-step progression into space and its winged configuration to aid re-entry.

In X-15's elliptical-arc flight, the pilot could be exposed to about 5 min. of weightlessness bio-engineers point out—substantially more than the 4.3 50 sec. produced in parabolic flight experiments. This would afford a preliminary and vital, insight to coordination and subjective adjustment of man to a new environment.

Intent of the X-15 designers is to feed in modifications to permit lengthening of the elliptical flight path, so that flight could be lengthened gradually to half way around the world and finally into an orbit about the earth. This orbiting could be accomplished within two years after the initial flight in 1959 if re-entry techniques are perfected and the whole man-machine system works out, bio-engineers say.

Change in tempo of the planning for out-of-atmosphere experiments since the X-15 was conceived, plus Russian achievements, has prompted Air Force planners to accelerate the time period in which man could orbit the earth and return safely. Any data generated in X-15 trials will increase the foundation of knowledge for the Man In Space Soonest (MISS) program—particularly information on re-entry, the most critical aspect of the manned satellite program.

Funds Not Pinpointed

Even though funds for Air Force MISS program are not pinpointed, Air Research and Development Command has started to turn gears for the project by requesting technical presentations from industry members and NACA. Schemes for satellite capsules were outlined at briefing sessions at the end of last February. Industry companies that

Manned Satellite Breakdown

24-Hr Flight Duration
300-Mi.-Altitude Orbit
Approximately Circular

*Payload	855 lb.
Capsule	70 lb
Structure	300 lb.
Insulation	70 lb
Beryllium Heat Sink	850 lb.
Retrorocket (for slowup to leave orbit)	250 lb.
Parachute Chest and Supports	100 lb.
Recovery Support Equipment	30 lb
TOTAL	2,545 lb
*Payload Breakdown (includes week's reserve)	
Man	175 lb
Oxygen and Purifier	85 lb
Water	20 lb
Food	10 lb.
Clothing	110 lb.
Temperature Control	130 lb
Attitude Control	85 lb
Communication	85 lb
Navigation	45 lb
Physiological Experiments	25 lb.
Neurological Experiments	20 lb
Physical Experiments	20 lb
Telemetering	45 lb
TOTAL	855 lb

participated included Aeronutronic Systems Inc., Lockheed Aircraft Corp., Boeing Airplane Co., Douglas Aircraft Co., Republic Aviation Corp., Northrop Aircraft, Inc.

Weight and configuration of capsule-satellite proposals vary, depending on specific design concept and details, orbiting period, equipment for experimental observation and supplies. Representative payload and weight breakdown for a manned satellite for a 24-hr. travel duration in an approximately circular orbit at about 300-mi. altitude may be broadly apportioned to include 855 lb. for the man and his supporting machinery, such as supplies, controls, biological equipment, communications, telemetering, and 1,690 lb. for capsule structure and related equipment, making a total of 2,545 lb. Specific figures relating to the manned vehicle are given in accompanying table (see above).

Types of Vehicles

Two general types of vehicles are likely to emerge as possible configurations for initial manned satellite.

● Relatively wide, delta-type vehicle with lift characteristic supplied by overall configuration or wings. Re-entry with this vehicle would use very shallow path for long, gradual letdown. Re-entry angle would be somewhere between 1 and 4 degrees to keep heat rate down to a tolerable level. Blunt nose and blunt airfoil leading edge or perimeter sections would help reduce aerodynamic heating. Proper materials would facilitate radiation of heat generated, and proper heat design would minimize cooling requirements, keep weight requirements down.

Big area would be needed for landing, and controls probably would be provided for slowdown in impending overshoot and for boost in undershoot condition.

Some design thinking emphasizes the ability to land on water because of the relatively vast expanse available. Others say this may not be feasible because of difficulty in finding a large expanse of water sufficiently smooth to accommodate a landing.

● Ballistic missile nose cone type configuration. This could be a hemispherical body or a blunt-nosed conical section. Inner capsule would be separated from the thick outer shell by insulation and air pockets. Hemispherical body could be stabilized by fins at the base for nose-first re-entry. Conical configuration could be stabilized for nose-first re-entry by proper disposition of weight in the forward section. Another scheme is to change capsule attitude for re-entry so that the base of the conical section points forward, presenting a higher

drag surface constructed to absorb heat.

This type of configuration generally cuts through the atmosphere at a relatively steep angle, the body heats up rapidly, but re-entry is accomplished before high heat is transmitted to the capsule interior because of relatively short time of passage. This type of configuration also might be made to enter the atmosphere at a shallow angle. At approach to the earth's surface, capsule parachute could be deployed for easy letdown, or possibly man himself could be released by parachute.

In the trajectory up into orbit, and in the re-entry phase, man will be strapped in a seat or cradle-type support to keep acceleration forces transverse to his head so that too much blood is not drawn away or delivered. But in orbit it might be feasible for man to unstrap himself, some observers feel, to avoid excessive fatigue and make observations. Unstrapped, he would float free and the effect would be as if he were in a "spherical canoe," where any motion, no matter how slight, will affect the satellite's orientation with respect to earth.

Importance of Stabilization

This underscores the importance of satellite stabilization to avoid any shift or tumbling that could seriously impair the functioning of man's system.

Various schemes are being investigated or developed to stabilize the satellite's attitude with respect to earth. These include:

- **Reaction jets** protruding from satellite.
- **Double pendulum** arrangement, comprised of a bulge on one side of satellite itself coupled by a viscous fluid to another pendulum inside the satellite. This is a passive type of stabilization, which might be used for a long life satellite to conserve power.
- **Inertial wheels.** This scheme would involve three motor-driven flywheels with axes perpendicular to each other. Motor frames would be attached to satellite frame, so the satellite could be rotated in the desired direction by starting flywheel in opposite direction.

More than any previous manned vehicle, the manned earth satellite will emphasize the necessity for closest coordination between human factors groups and engineering groups. This cooperation—a blending of concepts and requirements—will have to be initiated at the roots of the manned satellite project, so that each phase in the progression will stress man's efficient functioning and his safety. Members of the various segments of human factors groups will have to feed in opinion and data on the concept of the vehicle design for adaption of man to machine, test limits, and coordination for final operation.

Because man will be functioning in a relatively rigid state of confinement in the new out-of-atmosphere environment, his existence will in a sense be a designed one. How man fits into the instrumented and automated scheme in an earth satellite is debated with extreme disagreement in scientific circles. Some insist that there is little point in carrying man because instruments can do a required job better. Others maintain that man's ability to make difficult judgments with respect to unanticipated data, his ability to observe, compare, analyze and monitor, his flexibility in being able to alter original plans fit him for the satellite role. In any event, man's curiosity and determination to cope with the unknown will dictate that he go along on out-of-atmosphere exploration.

The question then resolves itself to a decision on what duties he should perform. Opinion is that initially he will go along mainly "for the ride," but as the implications of the manned earth-satellite are understood more fully and out-of-atmosphere exploration is extended, functions performed by man will be highly selective, supplying interpretation of data, follow up action, and final judgments far beyond the intelligence capability of the vehicle's machine components.

Despite the extensive cabin ecology

studies on earth and those conducted at relatively high altitudes on reaction of both man and animals, many of the human factors answers won't be supplied unless these are obtained under extended true out-of-atmosphere conditions.

Problems include:

● **Human reaction** to satellite cabin isolation. Ground experiments on isolation involving a work and rest schedule and studies on "total" isolation have given researchers a fairly good insight to the psychological hazards that might be encountered in space and the methods for combating them. "Total" isolation experiments indicate serious psychological results and limited exposure capability to the extreme condition. Longest period man has withstood this type of isolation in Air Force experiments is 70 hr., and even then really complete isolation cannot be simulated on earth. Subjecting man to cycles of work and rest help combat psychological effects of isolation.

One important difference in simulated isolation and the condition of isolation which would be encountered in a manned satellite is the element of fear. In the grounded "space cabin" the subject knows that, regardless of how severe or protracted the isolation, emergency relief is available immediately from the monitors of the experiment. This knowledge alone lessens the stress imposed by the rigors of the isolation trial.

In the orbiting satellite the more "absolute" isolation, with the absence of observers, newness of the environment, knowledge that critical equipment might malfunction, and knowledge of re-entry hazards, should create a buildup of mental stress far more severe than any experienced in simulated ground trials. Even loss of radio communication, could be a telling psychological blow.

● **Effects of prolonged** weightlessness. Limited experiments in aircraft have helped researchers anticipate what physical and mental effects may result from zero gravity condition, but specific psychological and physiological ramifications of weightlessness resulting from hours or days in an earth satellite will be resolved only by actual trial. This factor alone justifies early manned flights in earth satellites to pave the way for further exploration of space, some observers believe.

● **Effects of cosmic** and other extra-terrestrial radiation. Opinions differ on the extent of the radiation hazard. Experiments have been conducted with mice and other specimens such as yeast cells and fertilized eggs of sand crabs, and observed changes have been attributed to cosmic radiation. Undoubtedly this testing will be accelerated and broadened to precede man's inclusion in an earth satellite.

Effects of sudden burst of cosmic radiation stemming from large solar flares is one subject of speculation. These large flares are comparatively rare and timing for exposure may be difficult. Studies of one solar flare in February, 1956, showed that 130 roentgens would have been received by a space crew in an 18-hr. period.

Galaxy itself probably has a magnetic field and acts like giant cyclotron, speeding up charged particles from the sun or other stars. These particles may have energies of the order of 10^8 to 10^{10} volts, would penetrate the satellite and may knock out a human cell without causing excessive damage, it is believed if considerable mass of shielding is interposed. The primary cosmic particles (hydrogen nuclei and helium nuclei) would be slowed and made more dangerous, it is felt, since in this slowed condition they would hit more molecules in the body and capsule material, causing more extensive damage. This implies that improper amount of shielding might prove catastrophic.

Shielding will be required to cut off sun's radiation in X-ray and ultraviolet regions of the spectrum, indicating the extent of cooperation and compromise involved in resolution of design and bio-technical problems.

Observation windows in satellites might introduce a dangerous condition in the transmission of ultraviolet rays. This may require mirrors to reflect the light to a filter to protect an observer's eyes.

Small Animal Studies

Out-of-atmosphere studies with small animals in ballistic missile nose cones and non-recoverable satellites will precede any initial launching of manned satellite. Mouse earned in nose cone of Project Able's Thor-Vanguard second stage firing (AW Apr. 28, p. 37), was the first in series of ballistic missile booster tests with small animals included. Animals will range from micro-organisms up through chimpanzees before man is sent into orbit.

Non-recoverable satellites would afford a good opportunity to study the efficiency of a space cabin from the ecology viewpoint for periods up to the lifetime of satellite. Opinion is that it would be a challenging project to keep small animals alive for very extended periods under these circumstances, far beyond dog Laika's span in Sputnik II. Action of a small monkey or other animal, trained to get at a food box, will be recorded by telemetering or television cameras to furnish data on the active role of life under orbiting conditions. ■

NAVY'S 50-ft. human centrifuge at Johnsville, Pa., gains data on tolerance G-loads, has had major role in X-15 program.

Medicine Paces Man's Flight in Space

By Craig Lewis

As space technology brings man closer to his first flight in a satellite, space medicine has become an increasingly vital partner in the technical effort which will make manned satellite flights possible.

The farther man travels away from his natural environment the more precisely his vehicle must be tailored to his physiological and psychological requirements. Thus, progress in space medicine paces the evolution of flight into the upper atmosphere and beyond into space.

Despite the current controversy over the usefulness of man in space, it appears certain that he will go into space—if only out of sheer curiosity. Right now, human factors experts see no serious bars to successful manned space flight, and they feel the capability exists for short-term orbital flights. Extension of such capability in terms of time and distance in space flight is viewed as largely a hardware development problem.

Space medicine came to prominence only when the whole space flight problem came into focus after the first Russian satellite was launched, but it has rapidly risen to the point where it is substantial enough to be the subject of competitive jockeying in both military and industry circles.

Long-standing military space medicine programs, which often starved for lack of funds, now get strong backing. And industry has seen a sudden rash of expansion into the human factors field as contract possibilities for both industry and university projects became apparent.

Actually, space medicine is more an extension of many older fields of study than a new science by itself. Much space research is a matter of extending the altitude of aviation research done in the past and other knowledge comes from such sources as industrial fatigue studies and Navy research in submarine operations.

Part of the present body of knowledge stems from the brief forays man

MOUSE with magnets attached to feet is used at Navy School of Aviation Medicine to study use of limbs in simulated high gravity field, movement in zero gravity

has already made into the space equivalent regions of the atmosphere, such as the high altitude balloon flights made by Maj David Simons. Another step into the upper atmosphere will be taken when the X-15 goes into its flight program.

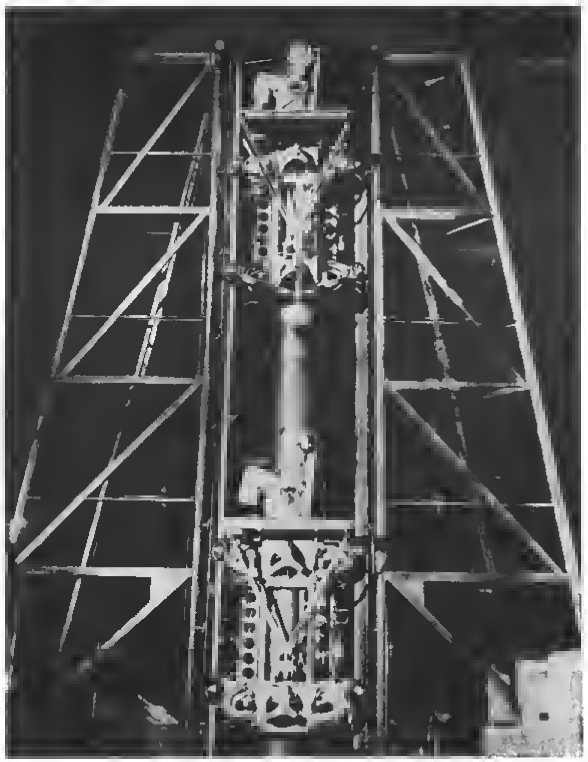
Although the X-15 is not a true space vehicle, the timing of its flight program will be helpful because of the information it will provide on some of the problems involved in putting man into orbit. The X-15 will provide some limited data on weightlessness, as well as information on the effects of such phases as acceleration and re-entry.

First true flight in space will come when a man is put in orbit around the earth, and the bulk of human factors work is now oriented to this task. It involves the specification of human needs and the formulation of reasonable human tolerances for the designers of the satellite. It also involves the study of the effect on the spaceman of new phenomena man will encounter.

Before the first man goes into orbit much experimentation will have been done with animals. Air Force and Navy both intend to use animals to explore the biological effects of space flight and to help prove out the operational aspects of satellites including their ability to bring their passengers back to earth safely.

While research in laboratories and in the near atmosphere has given space medicine a substantial grasp of the problems in space flight and many of their solutions, major questions remain to be answered. They involve the effects of prolonged weightlessness and cosmic radiation, and it appears that these questions will have to remain largely unanswered until orbital flight is achieved.

Most experts feel that cosmic radiation will not be a bar to space flight,



VERTICAL accelerator at Wright Air Development Center's Aero Medical Laboratory simulates re-entry buffeting. Seat moves 18 ft. up and 18 ft. down in two-thirds sec.

although some uncertainty was raised by reports of unexpectedly intense radiation at altitudes above 621 mi recorded by the Explorer satellites. This problem can probably be met with increased shielding, although scientists will have to determine the nature of the newly discovered radiation before they can specify the type and amount of shielding necessary.

Much data on the effects of cosmic radiation has been gathered by the Aeromedical Field Laboratory at Holloman AFB through balloon operations. Specimens ranging from radish seeds to monkeys were sent to altitudes where very little of the atmosphere remained to screen them from radiation. No radiation effects were detected which would indicate a major hazard to space flight.

Last year, Project Man High carried Capt. Joseph W. Kittinger to 96,000 ft. and Lt. Col. David G. Simons to 102,000 ft. in balloon flights. Simons stayed up for 32 hr., much of the time at 102,000 ft., and he reported no appreciable effects from radiation.

Effect of weightlessness on man in space is another of the major unknowns. Despite experiments in which very short terms of zero gravity have been induced, the final answer will not be known until man has spent a few hours in the weightless state.

Weightlessness has been induced at both Randolph AFB and Holloman AFB by flying Keplerian trajectories with T-33 and T-94C aircraft. These parabolic flights produce less than a minute of weightlessness, and although a faster aircraft might double the duration of zero gravity, the time span is still very small.

Test Findings

Some of the subjects in the Randolph flights enjoyed the sensation of weightlessness, other didn't like it so much, and about 25% of them developed motion sickness. Some of the minority who got sick eventually developed a tolerance for zero gravity, indicating that a relatively small percentage of space travelers will have a natural sensitivity to the weightless state.

Dr. Siegfried J. Gerathewohl, the scientist in charge of the Randolph zero gravity experiments, feels that the initial period of weightlessness is most critical because that is where adaption occurs. Thus Gerathewohl thinks that if a pilot tolerates weightlessness in the beginning of a flight, the chances are small of long periods of this unique state having unforeseen effects.

Attempts have also been made to simulate weightlessness on the ground to extend study over longer periods. At Wright Air Development Center's Aero Medical Laboratory, a platform supported by compressed air moves freely

and gives a weightless effect on one axis. A more elaborate structure under development by Antioch College for WADC will suspend a man in a frame supported on frictionless bearings. The rig will move in a cushion of compressed air and the subject will have a weightless sensation in five motions.

Experiments have also been done in fluids. Man's buoyancy is used to suspend him in water to simulate weightlessness. All of these methods produce some of the effects of the weightless state, but none produce the true effect of zero gravity. The subject's internal organs and systems for instance, are always subject to gravity.

Along with their tests of cosmic radiation, Man High flights were interesting because they employed a sealed capsule of the type that will have to be provided for man going out into space. The capsule has to control temperature, humidity and pressure within tolerable limits and it has to remove carbon dioxide and add oxygen to the cabin atmosphere. Water and food must be provided, and wastes disposed of.

Man High capsule performed the functions necessary for a short-term flight. As flight times increase, the capsule becomes more complex. For instance, on flights of a day or so, sufficient oxygen can be carried along in tanks. When flight times get longer, a self contained oxygen system which removes moisture and carbon dioxide will be necessary. And while waste disposal and water water supply are no problem on a short flight, a means of recovering water from wastes and from the cabin air will have to be developed for longer trips.

WADC Space Capsule

Once the human factors experts have told the engineers what the cabin environment must be like for a man in space, the extension of flight times is largely a matter of hardware development. Right now the state-of-the-art is close to being capable of supporting a man in orbit for a day or two.

Wright Air Development Center is contracting for a prototype space capsule which will have as much self-contained equipment in it as will be available when it is built. This prototype cabin, which will bring together the various types of systems needed to support a sealed environment, will be a research and development item, not an operational space cabin.

WADC has a closed oxygen system under development by Air Reduction Sales Co. It will remove carbon dioxide chemically, then remove moisture by cooling. New oxygen is added to the purified air, and it is pumped back to the man. This system, which combines known principles, has been developed to a container size where it can be strapped on a man's back.

Air circulating through the system could be used to cool the space man by circulating it through his suit. This system won't work in the weightless state because the water cooler uses a gravity feed, but work is being done to adapt it to use in zero gravity.

One possibility for a considerably more sophisticated cabin system lies in the use of photosynthesis. Using this principle, researchers at the USAF School of Aviation Medicine at Randolph AFB have kept mice alive in a closed system for several days. The system depends on the ability of algae exposed to light to absorb carbon dioxide and produce oxygen.

Since the algae grow, they may be harvester for food, and since they need nutrient human wastes may be processed to nourish them. Thus a photosynthetic system could perform a variety of functions. At this stage, such a gas exchange system is entirely too crude and unwieldy to operate in a space ship, but it holds promise for future flight phases when ships may go into space for weeks or months.

Pressure suits become more and more important as altitude increases and lightweight suits recently developed by the Air Force and Navy are significant steps toward efficient space travel. The space man will need a suit he can work and live in comfortably, and this means that more improvements will have to be made as flight times are increased.

Ultimate in suit capability will be the ability to do something like walking on the moon. Before that point of exploration is reached, use of a pressure suit will depend on reliability of the system. If space vehicles achieve a high degree of reliability, man may be able to take his suit off, but he will always have one along with him.

Escape from space vehicles is being explored, especially during the launch and re-entry phases. WADC is studying the effects of buffeting and oscillation in the transverse G field in its centrifuge, and further studies will be made in the larger Navy centrifuge at Johnsville, Pa.

Escape while traveling in space is a different problem. Leaving a space vehicle and returning to earth would require another space vehicle with a propulsion system and a supply of food and oxygen, and it would involve the same problems as ordinary space flight.

Effects of acceleration and deceleration have been studied by such means as Col. John Paul Stapp's sled runs at Holloman and the USAF and Navy centrifuges. Rocket thrusts and velocities for satellite launchings anticipated by human factors researchers are expected to keep these forces within human tolerances.

Researchers have experimented with the use of water to protect man from the G forces of acceleration. Centrifuge tests with the subject immersed inside a metal container showed that arms and legs could be moved freely, but the physiological effects were about the same as in a G suit. Since the heart and lungs were encased in air and didn't have the protection of surrounding water, chest pains developed as they would in a G suit.

Fluid Method of Protection

This fluid method for protection from acceleration was discussed several years ago by Dr. S. N. Stein, now with the Naval Medical Research Institute, in the Journal of Aviation Medicine. He suggested that filling the lungs with water with oxygen dissolved under pressure and properly adjusted for various characteristics, as well as surrounding the man with this water, might conceivably sustain life. With an incompressible fluid around and within him, man would be better protected from G forces. This airtight is one that would require considerably more experimentation before it could be considered a reasonable solution.

One of the psychological problems in space is the fact that it represents nearly a sensory vacuum, something man has not experienced. A key factor in the new space environment will be man's ability to use his senses without such usual sensory aids as sound, scattered light and points of reference.

Basic research in pure isolation is done at WADC with an anechoic chamber to test the effects of isolation and confinement on the pilot of a one-man space ship. Subjects are confined in the soundproof, light-proof room in a state of pure isolation, then various stimuli, such as unpatterned sound or light, are introduced.

By subjecting men to space-type stresses now the isolation tests should also be valuable in determining what type of man is psychologically suited to space flight.

Human tolerance to heat will be an important consideration in space vehicle design, especially for the launch and re-entry phases of flight. WADC has tested man's tolerances in heat chambers, and a new chamber, which will be finished this summer, will broaden experimental parameters. It will produce temperatures ranging from minus 50F to 500F, and will vary humidity, take altitude to 100,000 ft. and induce wind velocity up to 10 mph.

Navy has a human calorimeter at its

Bethesda Research Institute which is used to determine how long a man can stand high temperature and how fast he will accumulate heat to an intolerable degree. Temperature in the calorimeter can be controlled at levels between 35 and 180F and measurements made of the heat produced by the subject at each temperature, as well as oxygen consumption and carbon dioxide production.

Calorimeter studies of heat loss rate and evaporation cycles can be used to determine ranges of environmental temperature where man's requirements for such energy fuels as oxygen and food are smallest.

Probably the best publicized of space medicine work has been the recent simulated space flights in cabin simulators at Randolph and WADC. In the Randolph experiment, a volunteer airman spent seven days in a sealed capsule working on psychological problems under a planned work-rest schedule. In the cabin, fresh oxygen was supplied and carbon dioxide removed, and the temperature was kept near 75F while humidity ranged between 40 and 52%. Pressure was at the 18,000 ft. level.

At WADC five men lived together in a space cabin simulator for 120 hr., working according to preset schedules on a mission which simulated orbital flight. In this test the crew was made as comfortable as possible but was completely cut off from the outside world except for scheduled reports over check points involved in the mission.

Value of Simulated Flights

Not much new is learned from these simulated space flights, but they have their value in studying the effects of confinement on both the isolated single crewman and the group of crewmen who must work together over long periods. They also have the value of bringing a number of the psychological stresses expected in space flight together in one experiment giving researchers some idea of the interrelation previously studied separately.

Work cycles for space crews are one factor with which the space cabin simulators can help researchers. At Randolph, the subject who was alone for seven days lived under a schedule of four hours on duty and four hours off. While tasks imposed under this schedule kept his mind occupied and eliminated such problems as hallucinations, the cycle failed to combat fatigue, and proficiency fell off after the third day.

In the WADC experiment the crew members worked and rested on much longer time cycles. Pilot, copilot and flight engineer worked 16 hr. out of 24. Yet performance remained generally high. For flights in space over long periods of time, a work-rest cycle some

where between the Randolph and WADC schedules will probably be prescribed to maintain maximum performance

Navy Research

Navy has done considerable work on man in confined isolated environments which contributes to space medicine. Much work along these lines has been done in submarine research in the past, and the capability of nuclear subs for long underwater cruises increases the need for such work.

Dr. S. N. Stein of the Naval Medical Research Institute points out that space medicine and submarine medicine both deal with encapsulated environments. Evidence of this can be seen in a test chamber operated at the Bethesda Research Institute. Like the smaller chambers used by the Air Force in its simulated space flights, the Navy chamber provides a sealed environment in which 18 men can work and rest for prescribed periods.

Navy chamber has an adjacent hot room which can simulate an engine room or the hot side of a space ship. A second room contains a shower, heaters and air conditioning equipment. Air conditioning system controls humidity, removes carbon dioxide and adds oxygen as it circulates air. It can also remove or recirculate contaminants generated by the crew to determine the effects of these contaminants on men in a confined environment.

Since researchers are already working on nearly all the projects which can be done on earth, the next big step for space medicine will be to send biological specimens into orbit. Experiments with animals in satellites will be aimed primarily at studying the factors such as weightlessness and radiation, which cannot be studied on earth.

Both the Air Force and the Navy are ready to get into the satellite business when an official decision is made. USAF has animals at both Holloman and WADC. Air Force plans to train primates to perform tasks under simulation then send them up to see how they perform under space stresses.

Types of animals which go into satellites will depend to a great extent on weight limitations imposed by hardware capability. Flights are expected with rodents and small primates, but eventually researchers will want to send a primate like the chimpanzee into orbit because he is closer to man in size as well as other characteristics.

Navy is working with both rodents and primates at its Bethesda facility. Rats are small and hardy, and the fact that rats have been used widely in research makes it simple to assess their reactions to experimental conditions. Navy has confined a group of rats in extremely small cages to determine what effect confinement in a satellite might have on them.

One serious disadvantage rats have in space research is that they can't vomit. Since vomiting is a symptom of radiation sickness and may result from weightlessness researchers would like to be able to measure it. Other disadvantages lie in the fact that rats are harder to train than primates and don't have the human-type arm and hand structures of primates.

One prospect for space flight Navy researchers are studying closely is the cotton top marmoset. This monkey-like primate weighs only 1-2 lb. and appears to have roughly the same intelligence as a monkey. He is trainable and appears able to learn the psychomotor responses needed to test discrimination of muscular sensation in zero gravity.

Another prospect is the squirrel monkey, the smallest true monkey. This primate weighs 2-4 lb., is hardier and probably easier to train, according to Lt. Robert Voas of the Bethesda Research Institute. He also points out that the squirrel monkey has been used more often in experiments so more is known of it and it would be easier to interpret measurements of the reactions.

Use of primates in satellite experiments is advantageous because of the degree to which they can be trained. Psychological effects of prolonged weightlessness can be measured by their response in orbit to the same stimuli they have learned to respond to on the ground. Navy is moving into the training phase with its animals.

Before Navy would send animals into orbit they would be tested in pressure chamber and centrifuge to get a profile of their reactions to the various forces they will encounter. As with Laika in Sputnik II, the first animals to go up won't come back, so it's important to predict their life span accurately with the oxygen and food they will have with them. If they die before this span is up, researchers will be reasonably sure they died from some unmeasured effect, like cosmic radiation.

While test animals are orbiting in space, other animals from the same group will be kept in a simulated environment identical to that in the satellite. Comparing this control group with the animals in space helps to isolate space reaction differences.

Lt. Voas points out that an even more precise comparison could be made if a control group went along in the satellite. The control group would be placed at the periphery of a spinning satellite where centrifugal force would induce artificial gravity. The experimental group would be in zero gravity at the center. Thus, both groups would be subject to the same force of acceleration, radiation temperature and all other conditions but zero gravity, and any differences in their reactions could be pinned directly on weightlessness.

While the sizes of satellites and boosters for biological experiments haven't been officially described, it seems certain that they will have capabilities greater than those of the Vanguard and Jupiter-C rockets currently used in satellite launchings. Although weight is a crucial factor in the choice of animals, researchers may want to send a number of small animals rather than one large one on some flights in order to improve their statistical samples.

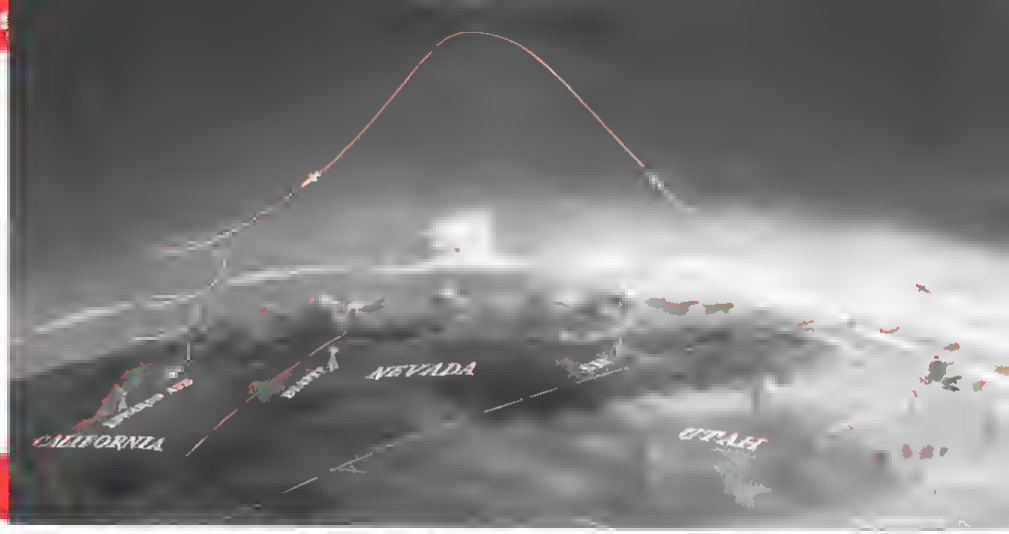
While the first groups of animals to go into orbit are not expected to return to earth eventually they will have to be brought back safely in order to complete experiments on space effects.

Telemetering capability will be an important link in studying biological specimens in space, and the Navy has developed considerable competence in this field. It has been telemetering data from high altitude balloon flights since 1947 and has the equipment ready to go as soon as miniaturization problems are licked.

Telemetering for biological experiments is different from techniques used in missile tests. It must be tailored to the job of transmitting physiological data. Navy can telemeter information on the respiratory, circulatory, digestive, excretory, neuromuscular, cortical and temperature regulating systems. Telemetry will return 18 pieces of data and FM/FM telemetering systems now used on missiles could be adapted to medical use and provide data on 96 channels.

Importance of getting complete data on the first orbit is stressed by Capt. Norman L. Barr, chief of Navy's aviation and space programs. He notes that chances of a man dying in a satellite are most critical in the first orbit. And on the first flight, man may only stay up for one orbit. Barr says that ships and Minitrack stations can be oriented to get complete data on this first orbit.

Use of a telemeter telephone system developed under Captain Barr's direction can aid in speedy gathering of data from orbiting satellites. Telemetered information can be relayed from ground stations by telephone lines to a central data processing point, and ships can relay data by radio. ■



FLIGHT test work on X-15 will be carried out on a special range. B-52 will release X-15 over Wendover, Utah.

X-15, Dyna-Soar Will Put Man Into Space

By Richard Sweeney

With his common sense and his ability to anticipate and discriminate, the human pilot has insured his role in space craft, although he may serve predominantly as a monitor and decision maker and become part of control loop only in direct emergency.

USAF, prime backer of the weapon systems that will put man into space, has proceeded on the basis of manned systems and projected Dyna-Soar, the orbital, hypersonic glide bomber, as a piloted weapon.

Before Dyna-Soar, for which two Phase I study contracts have been awarded, can achieve technical soundness, USAF's first manned vehicle to probe into space will have gathered much data necessary to Dyna-Soar's design.

The rocket-powered X-15 research air/space craft, a joint venture of USAF, Navy and National Advisory Committee for Aeronautics with NACA as technical director, will collect preliminary information on:

- Various aspects of aerodynamic control, stability and maneuverability in the atmosphere, on its fringes and in space at hypersonic velocities.
- Structural problems in airloads, as well as aerodynamic heating and accelerations.
- Human factors, such as the effects of weightlessness for measurable periods, effects of accelerations, performance of the pilot functioning in the control loop as well as monitoring automatic or semi-automatic control systems.
- Flight techniques for re-entry and deceleration, two critical areas.
- Materials. Although not presently part of the X-15 flight program, flights at later dates undoubtedly will involve various new materials and construction techniques.

The X-15, designed and built by the Los Angeles Division of North American Aviation, Inc., is constructed primarily of steel. It will have a thrust/weight ratio at launch of approximately 2 to 1. Although it will carry man higher and faster than any vehicle preceding it, it will not in itself represent any breakthroughs in aircraft design.

Proven Techniques

Starting from the basis of proven techniques in all areas, X-15 is not a completely optimized vehicle. Where compromises to hold to time limits or safety standards which present acceptable risk levels were indicated, compromises were made.

Although no radical breakthroughs are presented, the X-15 design does represent very advanced concepts of proven design. For instance, a nickel alloy steel has been used as "armor" against aerodynamic heating with titanium and stainless steel structure underneath.

X-15 configuration is basically a body of revolution, with triangular shaped blisters rounded on top running down each side of fuselage from just aft of the pilot's compartment to the tail. Wings project from this, as do the horizontal stabilizers. Round top of the blister flattens toward the rear, and where wings, stabilizers are mounted. All controls plumbing and wiring from the pilot's station to the powerplant section and control surfaces are carried in the blister.

Fuselage, approximately 50 ft. long is integral fuel and oxidizer tank of relatively thin-walled stainless steel. A substantial circular member running longitudinally along the neutral axis of the aircraft provides structural strength, also serves as a line from the fuel and oxidizer tanks to the powerplant. Circular belt frames are used, spaced approximately 4 ft. apart with three equal-spaced beams extending radially from center member to belt frame. Fabrication is by welding.

Fuel and oxidizer tanks have radar dish shaped baffles to minimize fuel slosh especially to help prevent significant shift of mass during periods of weightless flight should a quantity of propellants for use at re-entry be left aboard unused.

Wings are thin, supersonic profile and incorporate supersonic ailerons for

flight in the atmosphere Trailing edges are blunt Leading edges are fairly sharp but not so much so as those of the F-104. However, in relation to the thickness ratio, leading edges have a fairly large radius, resulting in a condition resembling bluntness to minimize leading edge aerodynamic heating

Wings are low aspect ratio Leading edge is swept back but not sharply Trailing edge is swept forward a few degrees Wing span approximates 22 ft

Horizontal all-movable tail has a swept leading edge and 15 deg of anhedral to aid stability Trailing edges are blunt

Vertical surfaces have a swept leading edge and a slight forward sweep on trailing edges One unique feature is the extreme bluntness with trailing edge of both upper and lower surfaces 12 in across Top half of the vertical stabilizer rotates for aerodynamic control similar to the Bomarc missile Ventral fin has no moving portion and is jettisoned for landing Top surface is approximately 5 ft high ventral about 4 ft

Landing gear consists of two retractable skids at rear, wheel in the nose

Powerplant is a 60 000 lb thrust liquid propellant rocket engine built by Reaction Motors, Inc Propellants are anhydrous ammonia and liquid oxygen Although changes can be made to other combinations should the plane's mission be changed

Propellants are pressure fed to the engine with helium used as the pressurizing agent Engine is controllable in the generally accepted sense of the word for rocket engines—that is it can be throttled through about 50% of its power spectrum but controls are provided which prevent accidentally exceeding the craft's or man's limitations

Control system for out-of-atmosphere flight consists of reaction jets powered by hydrogen peroxide monopropellant acting with a chemical catalyst to create a steam jet Ports about 1½ in dia are located on the top surface of each wing for roll control and on top and bottom and on each side of the nose for pitch and yaw control

When the reaction controls are used after the main engine has been shut down, they will result only in a change of attitude for the aircraft and not a change in flight path since they will merely rotate the airplane about its center of gravity With the main engine running change in attitude and hence thrust direction will result in a change of flight path

Pilot display for the X-15 will be a well combined system based on present displays, although there will be differences required by the changed frames of reference in out of atmosphere flight Guidance system will be inertial, feeding data to both the automatic flight control system and pilot display

Pilot's controls will consist of a right hand side stick for aerodynamic controls, since initial accelerations preclude effective work with the standard central stick Out of atmosphere reaction controls will be a small three-directional handle on the left hand console with stick movement to left or right controlling yaw, tilting left and right to control roll, movement fore and aft for pitch

Cockpit area becomes an escape capsule at high altitudes and a supersonic ejection seat with stabilizing vanes and shock wave generator for ejection at lower altitudes is incorporated

An essential part of the X-15 program is the pilot's space suit Weighing 13 lb it can be donned by the pilot alone, although he needs help attaching helmet An H-16 back pack contains emergency oxygen and pressure system Suit has exterior aluminized coating to reflect heat in case of emergency equivalent pressure inside equal to 25 000 ft Suit was developed by David Clark Co of Worcester Mass in a 10 year joint USAF Navy pressure suit program and is suitable for true space flight as well as very high altitudes X-15 suit is one of four prototypes, and allows the pilot freedom of movement heretofore unobtainable in full pressure rigs

Three X-15 vehicles are being built in the program, one right behind the other It is planned to complete and flight test all three vehicles as soon as possible, so that each can participate in the research flying All three vehicles are identical in all respects

B-52 Carrier

X-15 will be carried to altitudes on the order of 40 000 ft slung under the right wing of a modified B-52 since it is too large for the bomb carrying role in the X-1 and X-2 programs Due to the tankage configuration and fuel system of the B-52 balance is no problem

Use of this technique however cuts down flexibility for adjustments and minor malfunction corrections in the air if they show up on checkout just prior to drop Also the pilot will be locked into his vehicle prior to takeoff

Overall flight test program for the X-15 is being handled by a committee composed of USAF and NACA with the Navy maintaining liaison

Initial flight tests and contractor demonstrations will be handled by Scott Crossfield North American design specialist the first man to fly Mach 2 and veteran of more than 100 rocket flights

This work will be limited to altitudes and Mach numbers already achieved by others notably, an altitude of 126 000 ft reached by Capt Iven Kincheloe in

the Conquest of Outer Space...

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the X-2 and the approximate 2,100 mph achieved by Capt. Milburn Apt on the ill-fated last flight of the X-2.

North American has, however, designed a machine which, with minor modifications, is capable of orbiting flight, and the company has made a number of proposals to accomplish such work with the vehicle. With the variations available in boosters and in possible propellant combinations for the X-15, the company's proposal for Dyna-Soar probably is based on the X-15 itself or an extension of it.

Flying the X-15 for USAF's Air Force Flight Test Center at Edwards AFB will be Capt. Ivan Kinchloe, who participated in the X-2 program, and Capt. Robert White and Capt. Robert Rushworth.

First NACA pilot in the program is Joseph Walker with Neil Armstrong as backup. Jack McKay also will participate. All are research pilots at High Speed Flight Station at Edwards, which is the prime NACA group working on the program.

Different Procedure

With the X-15, a different procedure will be followed than has been customary on rocket research planes.

Since all three X-15s will be identical and will follow each other into service relatively closely, all three will be used simultaneously. Two and even three flights a day might be accomplished, using all three vehicles, or day-after-day flights might be made, using the vehicles in sequence.

In addition, both USAF and NACA pilots will participate in the day-to-day flight investigations. It is now planned that while North American does first flight and required contractor demonstrations, Kinchloe or other USAF pilots will explore the airplane's maximum speed and altitude envelope.

Mother ship will be under USAF supervision and use an AFFTC pilot, probably Capt. John Gain. Stanley Butchart, NACA research pilot who has regularly flown the mother ship in recent work with the X-1B and X-1E, probably will ride the B-52 also.

The X-1B and X-1E, variations of the basic X-1 configuration, have been used extensively to investigate jet reaction controls and other X-15 design problems. Controls are attached to the X-1B, with roll jets on wingtips, pitch and yaw jets located in the empennage area.

NACA pilots on the X-15 program will work on complete investigations, gathering the thousands of data points required for upcoming space vehicles and weapon systems such as Dyna-Soar.

Flight test work will be accomplished at Edwards AFB on a range specially laid out for this type work. Since the X-15 has a nominal distance-covering ability of 450 mi., upper end of the range where the X-15 will be released is at Wendover, Utah. It terminates at Edwards, where X-15 will make its landings on Rogers Dry Lake.

Range instrumentation, differing from that of conventional facilities and specifically engineered to this new type of mission, is located at Wendover, Edwards and at intermediate points in Ely and Beatty, Nev. Range course is such that flights will be over sparsely populated desert areas.

First flights, with the X-15 carried aloft just to check handling and other aspects of mother ship operations, probably will take place late this summer, followed later by unpowered glide flights in which the X-15 is dropped to sample its low speed and landing characteristics. First powered flights are expected early in 1959.

With the X-15, research flights will be in the nature of incremental advances in whatever investigations are being conducted. Believing steady but cautious advances pay off in safety, (X-15s will cost several million dollars per copy, not counting the amount of research and development that went into them) and yields better data as well, NACA wants to advance the program as fast as possible consistent with all other factors.

And while X-15 investigations will help such programs as the B-70 and L-108 to some degree, Dyna-Soar probably will be built on sound technical data derived very largely from X-15 flight test work.

With today's knowledge, several approaches are possible to the manned orbital, hypersonic glide bomber.

Although USAF specifications on which Dyna-Soar bids were submitted probably were very general, combining an orbital bomber and hypersonic boost-glide type vehicle would offer several advantages such as dual mission capability, flexibility.

Some generalizations on problems involved in Dyna-Soar would include:

- Unless a highly accurate control system is devised, an orbiting bomber would have to be extremely closely pre-programmed to follow a useful flight path.
- Way to successfully dispatch the weapon from the bomber would have to be found.
- Orbiting vehicle would be extremely vulnerable in a fixed path and an adequate defense system would have to be developed.

It is quite possible that the control and vulnerability problems led to the dual role of orbital hypersonic glide vehicle. For the glider departing from orbit essentially replaces ground launch and greater flexibility is obtained in leaving orbit with a global range (11,000 naut. mi.) hypersonic glide bomber.

since corrections for slight errors can be accomplished.

Another aspect is that while functioning in orbit, the vehicle could, if suitably equipped, perform the reconnaissance mission.

As a weapon delivery system, hypersonic glider would have a greatly lessened defense problem, once orbit is left.

On the other side of the coin is the fact that for a ground launch and purely hypersonic glide bomber, either launch could be effected with lower total gross weights, or else additional payload could be carried if the booster used is the same one which starts the vehicle toward orbit.

Problems facing designers of hypersonic glide vehicles might include:

- **To achieve the global** range, mission might run as long as two hours in the atmosphere, result in steady state heating to temperatures as high as 2,300F.
- **To achieve a final** velocity with gross weight of less than 25,000 lb., three stages of rocket engines would be required for launch, the first capable of at least a 1,000,000 lb. thrust, second at least 250,000 lb., the third between 25,000 and 30,000 lb. thrust.
- **An L/D ratio of close** to 5 would be required.

As the satellites circle the earth gathering data on fringes of the earth's atmosphere, space flight problems may appear which had not been fully appreciated previously.

These could include effects of meteoric dust and particles in the abrasion of structures. At the high speeds involved they might have severe effects on the aerodynamic configuration, the strength and thermal characteristics of structures over a period of time.

It also may be possible that drag resulting from electrical fields caused by the sun's radiations in the far ultraviolet spectrum might be encountered.

Another area where development is sorely needed is in reconnaissance methods. Hypersonic speeds in atmosphere generate shock waves which severely attenuate infrared scanning, radar waves, camera and other optical systems. There is an urgent need for an airborne system utilizing passive techniques, emitting no electromagnetic or other traceable and jammable radiation.

While formidable problems remain to be solved there has been extensive work in several areas leading to hypersonic glide and orbital manned weapon delivery systems.

Magnetohydrodynamics may offer answers to part of aerodynamic heating through drag and boundary layer control. Ablating materials or even a cooling fluid system might prove feasible.

Another approach is use of an exterior heat resistant shell, under which

is insulation, and under this, the primary load carrying structure which could be made of today's standard materials of light weight.

Additional work has been done in heat resistant outer structures to allow for thermal shock and expansion.

Considerable research into possible aerodynamic configurations has been accomplished by NACA and the results widely disseminated.

Consideration of purely aerodynamic factors in configurations is necessarily limited due to structural requirements to beat the heat and propulsion requirements. Even if the last stage of the primary propulsion system is not a part of the glider, the vehicle still will require propulsion for orbit departure and attitude control at re-entry.

Boosters for hypersonic glider present enough problems in themselves but when vehicle and attendant payloads for weapon delivery also are to be placed into orbit increase occurs.

One area in propulsion which will require the most effort will be redefinition of term "reliability" to insure that when it is used it has common meaning to all concerned with the projects. What constitutes reliability for ballistic missiles does not necessarily bear much relation to the meaning of the word in connection with manned system.

Although large liquid propellant rocket booster engines usually are thought of for such systems, solid propellant engines also are to be considered. However state of development in liquid rockets with the ability to throttle and gimbal will continue to weigh heavily for these types for this mission.

And although present propellant combinations pose handling problems, storable propellants are coming along which promise specific impulses more than adequate for the mission. Another aspect of this is that in seeking much higher specific impulses, the penalties of certain exotic propellants may well be worth the extra effort their handling requires.

A proposal for a first stage booster has been made by General Electric Co. which is built around high thrust Mach 4 turbojet engines in clusters to form a very controllable, recoverable and reusable initial stage. This system would boost the weapon system to more than 50,000 ft. and Mach 4 before firing of first rocket stage. If successful it would reduce need for large, heavy initial rocket engine boosters.

A wide variety of weapons will be available for use with hypersonic glide bombers. Missiles both guided and unguided and ordinary trajectory bombs could become a part of the weapon system, all with high yield thermonuclear warheads. ■

NAVY-MARTIN Vanguard vehicle prepared for launch at Air Force Missile Test Center, Cape Canaveral, Fla.

Satellites

PITCH and yaw vane is unlocked on vehicle that put first Vanguard satellite into orbit. Space vehicles will use Vanguard engines.

Vanguard Components to Get Wide Use

By Evert Clark

The Vanguard satellite vehicle, developed with a low priority on a small budget and often plagued by Congressional criticism, already has contributed far more to the nation's space programs than originally intended.

All three services have plans to use components of the launching vehicle in other spacecraft, and the vehicle can put more than 70 pounds into orbit as it exists now.

In addition to the contributions that various stages will make, the vehicle itself also may have direct military applications. Dr. John P. Hagen, director of the Vanguard project at the Naval Research Laboratory, has pointed out that "there are certain things still about this vehicle that we hold in a classified category."

Vanguard's second-stage Aerojet engine already has been fired atop an Air Force Thor intermediate range ballistic missile booster to test re-entry, separation from the Thor booster, in-flight ignition and physiological effects on the nose cone's passenger, a mouse.

Navy Follow-Up Program

Navy has proposed a follow-up satellite program using the Army's Jupiter IRBM, topped by the upper two stages of Vanguard.

Air Force's Project Able and Project Bravo, test shots leading to launching of lunar probes, will continue to use the Aerojet Vanguard engine, as will the lunar vehicles themselves.

Navy has proposed launching a series of satellites with payloads of 50 to 300 lb. This may be the Jupiter-Vanguard vehicle proposal or a separate program.

Even without these follow-on programs, Vanguard vindicated itself last March 17 by putting a 6.4-in., 3.25-lb. satellite into an orbit with a 2,513 mi. apogee and 407 mi. perigee, and also orbiting the solid propellant third-stage Grand Central Rocket Co. engine, which weighed more than 50 lb.

Dr. Hagen said the third-stage engine also can be orbited along with the heavier 20-in., 21.5-lb. scientific satellites assigned to the Vanguard program.

The Grand Central engine has a high specific impulse and delivers about 2,350 lb. thrust. Allegeny Ballistic Laboratory, Navy-owned and contractor-operated by Hercules Powder Co., still is working as an alternate source for a third-stage solid propellant engine which may be even more powerful.

Finally, although Vanguard is a tri-service project supporting the U.S. part of the International Geophysical Year program, work on the vehicle has been contracted, supervised and coordinated by Navy, and Vanguard might well play a part as a test vehicle in the early steps of a Navy manned space flight program.

Rear Adm. J. T. Hayward, Assistant Chief of Naval Operations for Research and Development, has said that Navy's "definite" plans for future space efforts include putting man into space, and Bureau of Aeronautics has studied the use of a hypersonic glider aircraft that would be able to operate from a submarine.

Earlier Space Efforts

Vanguard is by no means the Navy's first effort in the space field. It began participating in research and development studies directly related to space travel 16 years ago, in 1942. These initial studies established the feasibility of creating a man-made earth satellite program.

In 1945 the Navy proposed that a satellite project be initiated. The launching vehicle would have been composed of clustered rocket stages. The Committee on Guided Missiles of the Defense Department's old Research and Development Board rejected the proposal.

In June 1954, the Office of Naval Research and the Army's Redstone

Arsenal proposed the use of a Redstone ballistic missile topped by three clustered stages of Loki rockets to put a series of small satellites into orbit. First was to be a 5 lb. sphere in a 200 mi. orbit and later payloads were to be 10 lb.

Known as Project Orbiter, this suggestion was implemented and some components were developed, but the Vanguard program was to supersede it.

When the United States decided to follow the international IGY committee's recommendation that thought be given to the launching of small satellite vehicles to their scientific instrumentation and to the new problems associated with satellite experiments, a committee of the National Academy of Sciences and the National Science Foundation studied feasibility of such a project and recommended to the White House that it be undertaken.

On July 29, 1955 the White House announced that the U.S. would attempt to launch a satellite during the IGY (July 1, 1957 to Dec. 31, 1958) and said Defense Department would implement the construction and launching of the satellite-carrying rocket. One specification was that it be divorced from ballistic missile programs.

A Defense Department Committee on Special Capabilities studied the proposals of each service and decided, according to Dr. Hagen, that the proposal made by the Navy stood the best chance of "giving scientists the kind of vehicle they needed to do their scientific work."

The choice of Vanguard over orbiter was based primarily on payload a critical factor if the program was to be scientifically useful.

Viking Was Forerunner

Under the leadership of the Office of Naval Research, Naval Research Laboratory was selected to implement the Navy's part of the program because of its experience in rocketry and upper atmosphere research with the captured German V-2s, the Aerojet Aerobee sounding rockets and the highly successful Martin Viking program under NRL's Milt Rosen.

Viking, taking off from the V-2 design and powered by a Reaction Motors Inc. engine pioneered integral tankage and led to the swivelled engines and jet roll control of the Vanguard. It provided a 145-in. long payload section carrying 500 to 2,000 lb. and its 0.80 mass ratio allowed it to set a number of altitude records. In 12 firings Vikings exceeded a 130-mi. altitude five times and went below 32 mi. only once.

The program ran from May 1949 to Feb. 1955 and included 41 experi-

ments in cosmic and solar radiation, temperature, pressure, ionospheric composition, photographs, etc.

Viking also became the workhorse vehicle for the first two Vanguard tests after NRL chose Martin Co. as Vanguard's prime contractor.

On Dec. 8, 1956, TV-0—also called Viking 13—was fired from the Air Force's Missile Test Center to check out launching facilities at Cape Canaveral and the facilities of the 5,000 mi. range.

On May 1, 1957, TV-1 or Viking 14 was used to flight-test the Grand Central third-stage engine. Its unexpectedly high first-shot performance led to the use of the smaller satellite which became the first actually to go into orbit.

"The flight of the vehicle testing the third-stage engine was so successful that we were able to change the nature of the remaining test vehicle program," Dr. Hagen said. "In place of heavy nose cones filled with measuring instruments we were able to use a 6-in. sphere."

Following the usual development problems with the General Electric Co.'s first stage engine, the second stage engine and the vehicle itself, TV-2 was launched on Oct. 23, 1957, 19 days after the Soviet Union orbited a 184.3 lb. satellite. This vehicle contained the GE engine and dummy upper stages, but matched Vanguard's external configuration. The flight was successful, and Vanguard was batting three for three. Shortly afterward Vanguard finally was assigned top national priority.

On Dec. 6 of last year, TV-3—carrying a 3.25-lb. 6.4-in. sphere, rose only four feet from the launching pad before failure of the pressurization system in the first stage caused it to fall backward and explode on the stand. Criticism of the U.S. satellite program already high since Sputniks I and II exploded along with it.

TV-3 backup, the second vehicle to contain all three stages and a small satellite, was launched on Feb. 5 of this year. After 57 seconds the first stage engine control system began to fail and at 60 seconds of flight the engine deflected far to the right. Stress caused the rocket to break and the range safety officer blew it up.

1958 Beta Orbits

The successful orbiting of 1958 Beta by TV-4 last Mar. 17 has been followed by unsuccessful attempts to orbit larger satellites with TV-5 last Apr. 28 and the first Satellite Launching Vehicle (SLV-1) on May 26. There are five more SLVs in the original program.

Although the Vanguard program has launched a small satellite, it has not yet

rufilled its mission of placing a scientific satellite in orbit, determining the orbit and obtaining useful information from the satellite

After the small ball orbited NRL said there was some possibility but low probability of achieving four satellites in the seven tries that then remained but intuitive optimism based on general rocket experience suggests that the most probable number may be something like two With five chances left one successful orbit now seems more likely

The small 1958 Beta was the first satellite equipped with solar batteries—six of them provided by Army's Signal Engineering Laboratories and mounted on the surface It also contained two Minitrack transmitters on 108 and 108 03 megacycles and six antennas

One transmitter is powered by batteries, the other by solar cells One has its crystal attached to the shell the other to the inner structure so absolute temperature changes can be recorded These readings are providing design information for future satellites

The larger satellites are with one exception, 20 in magnesium alloy spheres, coated with gold chromium, silicon monoxide aluminum and more silicon monoxide They carry 10 75 lb of instruments of which about 8 lb are chemical batteries

The exception is a 13 in diameter plastic sphere to measure the earth's magnetic field It also will carry a 30 in inflatable aluminum sphere designed by National Advisory Committee for Aeronautics

Although the shifting of some instruments to Explorer satellites and Vanguard vehicle failures continue to alter the program, experiments planned were measurements of ionization solar aspect erosion micrometeor impact velocity and frequency ultraviolet and cosmic ray intensity geographical distribution of the energy received by and radiated from the earth and cloud patterns over the earth

The Vanguard vehicle weighs 22 000 lb and is 72 ft long First stage is 44 ft the second 31 ft and the third 7 ft

First stage uses lox and kerosene to produce 27 000 lb thrust the second white fuming nitric acid and unsymmetrical dimethyl hydrazine and the third an unspecified solid fuel Thrust is 2,350

First stage burnout comes at 142 sec and 33 mi altitude second at 258 seconds and 122 mi altitude and third at 555 sec and apogee altitude usually programmed at about 261 mi

Guidance consists of a pitch programmer coasting time computer with integrating linear accelometer, Minneapolis Honeywell three-axis gyro reference system, magnetic amplifier autopilot and program timer

First stage is separated by six explosive bolts Second is separated by retro rockets after a rocket-powered turntable spins up the third stage A delay fuse ignites the third stage. Nose cone separation is achieved by one explosive bolt which releases a spring, splitting the nose cone in two parts

Separation of the satellite from the third stage is accomplished by a timer-actuated spring

Roughly speaking a 1 degree difference in angle of injection can change the apogee and perigee by about 75 mi. If the angle remains constant but velocity varies from that planned the apogee and perigee will vary by 100 mi for every 100 mph difference

Tracking System, Cost

Vanguard is tracked by the Minitrack radio phase comparison, angle-tracking system from a fence of seven stations roughly along the 75th meridian These are supplemented by stations at Cape Canaveral, on the island of Antigua and two minor stations on Mayaguana and Grand Turk Islands along the Atlantic range, and stations at Naval Electronics Laboratory, San Diego, Woomera, Australia and Johannesburg, South Africa

Optical tracking is done by a network that eventually will have 12 prime stations and 200 secondary stations They are under the direction of the Smithsonian Astrophysical Observatory

Cost of Vanguard—$110 million—has been financed in this way

- National Science Foundation—$18 4 million, of which $13 4 was made available to NRL
- Defense Department emergency fund, Fiscal 1956—$15 5 million
- DoD emergency fund, Fiscal 1957—$70 8 million
- Classified non-defense source—$2 5 million
- Office of the Secretary of Defense contingency fund—$3.2 million
- Military appropriations (estimated)—$6 4 million
- Transfers from various Navy appropriations approved by Congress—$34 2 million

Considering that this money has financed development of a rocket vehicle that is capable of continuing scientific and military satellite experiments after the IGY ends that has contributed useful components to other space programs and that may have military application itself this may well be what Capt A B Metsger Deputy Chief of Naval Research, called it— the quickest and cheapest rocket project that has ever been seen — a bargain-basement job-

JUPITER-C, satellite launching vehicle for Explorer, is backed into Army Ballistic Missile Agency shop at Cape Canaveral, Fla.

Army Gaining Vital Space Assignments

On Jan. 31, 1958, the Army Ballistic Missile Agency put the first United States satellite into orbit and thereby filed its claim to space research and development Since then, ABMA has been given important assignments in the nation's space program such as:

- Mar 5, Agency launched Explorer II Mechanical failure in ignition system of last stage rocket prevented satellite from going into orbit after good initial trajectory.
- Mar 26, ABMA launched Explorer III successfully placing third U S satellite in orbit (Vanguard went into orbit March 17)
- Mar 27, Advanced Research Projects Agency authorized ABMA "to undertake one, and possibly two lunar probes" and "to launch two, and possibly three, earth satellites" Satellites will be continuation of Explorer program with some modifications in both the satellites and in the carrier rockets
- May 2, Army awarded $2 850,000 contract to California Institute of Technology for research on moon project Rear Admiral John P Clark deputy director of ARPA said he hoped to see satellite orbiting the moon before end of 1958

Satellite will be carried by Juno missile probably a combination of ABMA's Jupiter and components of the Vanguard or other missiles

Project Orbiter

The Army actually began its preparations for the space age long before the first Explorer took to the air It was during the first part of 1954 that the initial plan began to take shape

Soon after the Redstone had proven itself in flight tests. Dr Wernher von Braun now director of ABMA's Development Operations Division started toying with the idea of using the 200 mi ballistic missile as the first stage of a satellite carrying rocket On top of the Redstone, according to von Braun could be placed a rotating, cylindrical launcher, containing three clusters of small, solid propellant Loki rockets.

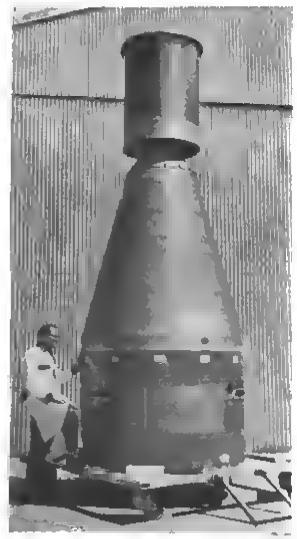
The Lokis, then under development were desired because of their short burning time about 0.8 sec The plan was for the Redstone to start the vehicle on its trajectory After two minutes, the Redstone engine would be cut off as the propellant tanks started to go dry A few seconds later, the Redstone would be separated, and the last three stages plus the satellite would continue to coast upward

Aligned by Air Jet

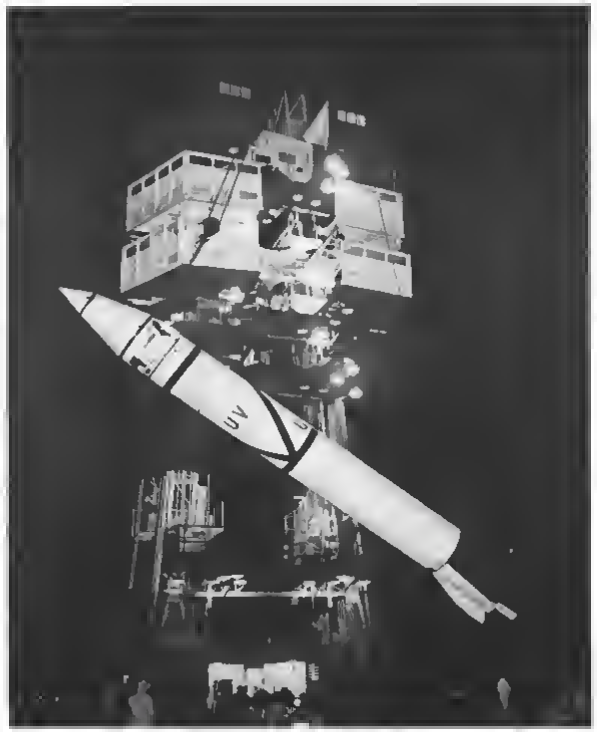
Just before the final stages reached the apex of their trajectory, compressed air jets would align the vehicle horizontally At apex, about 200 mi up, the spin-stabilized clusters of Lokis would be fired in order to bring the vehicle from a speed of around 6 000 mph to orbital velocity of 18 000 mph At this point the vehicle has no guidance, and it was believed that the incremental velocity would have to be produced almost instantaneously for the satellite to go into a circular orbit

This was the reason von Braun wanted the Lokis with their very short burning times Further analysis however showed that the firing time wasn't as critical a factor as first believed So when the larger more powerful Sergeant rocket engine came along it was used in place of the Loki Adoption of the Sergeant significantly reduced the number of solid propellant rockets needed This, in turn, meant an easier engineering job and increased reliability, i e fewer chances for failure in flight

While the idea was still in the planning stage, von Braun was introduced to Cmdr George Hoover of the Office of Naval Research ONR wanted to initiate a satellite projects based on existing hardware It liked von Braun's ideas and offered to put up the necessary money Maj Gen H N Toftoy, at that time commanding general of Red-



SPIN "bucket" and first-stage nose for Explorer vehicle at Reynolds Metals plant.



MAIN stage of Jupiter C is lifted by gantry crane in preparation for launching.

stone Arsenal and von Braun's boss, agreed to supply the required Redstone missiles and permitted von Braun's group to work on the program. Thus Project Orbiter came into being early in 1955.

Split Decision

Project Orbiter proved to have a brief existence at least officially. On July 29, 1955, the White House announced that the United States would attempt to launch an instrumented, artificial earth satellite during the International Geophysical Year. The services were asked to submit proposals on the project.

Army proposed Project Orbiter, the Navy offered what later was to become Project Vanguard. A top level committee, called the Ad Hoc Committee on Special Capabilities, was constituted to judge the proposals. On Aug. 4, 1955, Navy got the nod on a split decision because of its greater payload capability—anticipated at 40 lb. as against 10 for Orbiter.

Officially, the Army was out of the space and satellite business. But von Braun and other Redstone scientists continued to work on the project. They were joined in their unofficial effort by Dr. William H. Pickering, director of the California Institute of Technology's Jet Propulsion Laboratory. At the time, JPL was experimenting with a scaled down version of the Sergeant missile, which Pickering recommended to von Braun in place of the Loki.

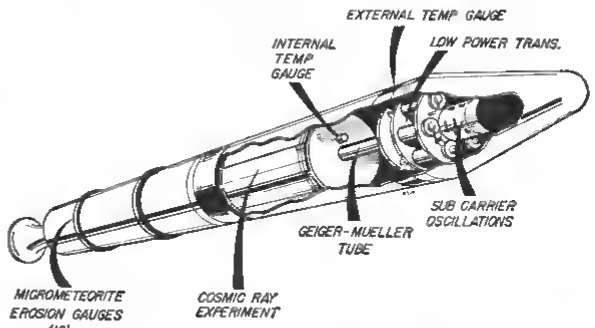
Then, in October 1955, the Army received authorization for the development of the Jupiter IRBM. To carry out the program, the Army would need, among other things, a re-entry test vehicle. This was the break von Braun and his group were waiting for. The modified Redstone which became the Jupiter C presented the Orbiter satellite rocket capability and at the same time provided re-entry test vehicle.

The Defense Department gave von Braun permission to modify 12 Redstones for re-entry test purposes. At the time, the Redstone, designed to carry an extremely heavy warhead, was only a 157 mi. range missile. It con-

EXPLORER is prepared for spin test. Upper stages are rotated to 700 rpm in check-out

sisted of two main parts: the body unit which held the guidance and control equipment in addition to the warhead, and the thrust unit which contained the propellant tanks and rocket engine.

To get the additional velocity required for re-entry, the engineers lengthened the thrust unit and inserted larger propellant tanks. This increased the burning time by almost 50%. Then two spin-stabilized clusters of scaled-down Sergeant rockets were sub-



EXPLORER III instruments measure cosmic ray intensity, temperature, meteor particles

stituted for the body unit and, wanting only a small, model nose cone, the Army's new re-entry test vehicle was ready to go It was called the Jupiter-C and with the addition of a single Sergeant satellite fourth stage was to become the Explorer

On Sept 20, 1956, the Army sent its first Jupiter-C on a 3,300 mile downrange trip from Cape Canaveral Two more test flights followed in quick succession, and then the rest of the Jupiter-Cs were put in a warehouse to gather dust for the following 12 months

When the first Russian satellite went into orbit on Oct 4, 1957, Secretary of Defense-designate Neil H McElroy happened to be visiting Huntsville He asked Maj Gen John B Medaris, commanding general of ABMA (Army Ballistic Missile Agency had been established at Redstone Arsenal in February 1956), and von Braun how soon they could have their satellite ready for launching and was told within 90 days of authorization

McElroy returned to Washington The second Russian satellite went into orbit November 4 On November 8, McElroy sent word to Huntsville, authorizing ABMA to prepare two back-up satellite vehicles for the Vanguard

There was little to do at Huntsville The rockets were ready The new liquid fuel, Hydyne, had already been proven out in full scale engine tests (Hydyne, a 60 40 mixture of unsymmetrical dimethyl hydrazine and diethylene triamine, was actually developed by Rocketdyne in 1956 at the Army's request for a fuel more powerful than the alcohol normally used in the Redstone It boosts the rated thrust of the Redstone engine from 75,000 lb to 83,000 lb)

The big job during this period fell to Jet Propulsion Laboratory, which had to make the actual satellite and the miniaturized transmitters Among the others that came into the project at this time were Dr James Van Allen of the State University of Iowa who furnished the cosmic ray instrumentation and the Air Force Cambridge Research Center which was helping with the micrometeorite impact experiment When these tasks were completed, Explorer I was ready to go

Secretary of Defense McElroy authorized the launching, and, on Jan 31, 1958, Explorer I took off into the night—84 days after initial (and formal) authorization

On March 5, ABMA tried and failed to put Explorer II into orbit The Agency had better luck on March 26, placing Explorer III—an almost exact duplicate of Explorer II—in an extremely elliptical but scientifically rewarding orbit

All three Explorers were equipped

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with a high and a low power transmitter and instrumentation designed to measure cosmic ray intensity, the effect of micrometeorites, and internal and external temperatures. Explorer I telemetered this information continuously on both transmitters with the result that much of this information was lost over the vast expanses where no Minitrack receiving nets existed. To remedy this a miniature tape recorder was designed to go with the high power transmitters in Explorers II and III. This recorder plays back data only upon radio command from the ground.

With Explorer III, the scientists also decided to eliminate the four whip antennas used on I and II, substituting a dipole antenna in which the satellite itself is the antenna. Observation of Explorer I showed that the whip antennas, causing the satellite like a turnstile were imparting an undesirable, propeller like spin to the satellite.

The nose cone temperature sensor used in Explorer I to measure aerodynamic heating on ascent was left out of succeeding models. And one of the micrometeorite impact instruments (the spring impact microphone) in Explorer I was replaced by an additional cosmic ray measuring device in Explorers II and III.

While a complete evaluation of the data being furnished by the Army's satellites will have to wait for a later date, they have already provided enough significant information to convince scientists that they would be a bargain at twice the price.

Among other things, for instance, Explorer I has demonstrated that space is habitable for man, at least as far as temperatures are concerned. Inside the stainless steel satellite temperatures ranged from 6C to 30C. Nor does micrometeorite bombardment appear to pose much of a hazard for future space flight. According to data already analyzed, an area one square meter in size will encounter a particle four microns in diameter or larger once every 100 sec. and a particle 10 microns or larger once every 1,000 sec.

Cosmic radiation is another story again and could create a very serious problem for manned space flight. According to data telemetered from Geiger counters aboard Explorers I and III, it appears that a space traveler would be subjected to 0.06 roentgens per hour, one half his weekly tolerance. The data indicate that the cosmic ray count reaches 35,000 per second at altitudes above 1,000 mi.

But adequate shielding, the scientists say, can cut radiation below human tolerance limits. Few scientists seem inclined to stop their newly begun assault on space simply because of radiation hazards. ■

PIED PIPER reconnaissance satellite will be put into orbit by Atlas plus another stage, probably a solid-propellant engine.

Test Firings For Pied Piper Due Soon

First test firing in USAF's greatly accelerated Pied Piper earth reconnaissance satellite program is expected sometime this fall, although launching of a complete satellite is considered to be more than two years away.

Now under direction of the Advanced Research Projects Agency, the program is being supported at approximately three times its pre-Sputnik financial level.

Lockheed Aircraft Corp., systems contractor for the WS 117L which it calls Advanced Reconnaissance Satellite project, has delegated a large part of the development task to specialized segments of industry to gain time and obtain the best available talent. Some 50 industry companies now are associated with Lockheed in the project.

Increased Emphasis

Wrath increased emphasis on military space programs and the interjection of ARPA, the civilian space agency, and some degree of White House direction into the picture have changed the nature of the Pied Piper effort considerably.

One difference is that Piper now must compete with other out-of-atmosphere programs for military and budgetary support.

ARPA has asked $152 million for military reconnaissance satellite for Fiscal 1959 compared to $55 million in Fiscal 1958. It also has asked for $138.2 million for other military space technology work that includes satellite tracking, monitoring communications relay, meteorological reporting, and navigational aid systems.

Piper is expected to continue to get strong backing from USAF planners. Among the vital considerations are:

- Soviets are working toward perfection of a similar satellite as an extension of earlier Sputnik developments (AW Oct. 14, p. 26).
- Pied Piper is a natural follow-up in the progression of data-gathering, earth-orbiting vehicles ushered in by experiments with Army Explorer and Navy Vanguard satellites.
- Intelligence supplied by system with reconnaissance capabilities planned for a vehicle such as Pied Piper represents ultimate transmission dividend demanded of an earth satellite. Pied Piper's picture transmitting mission becomes a logical, urgent goal now that ability to put vehicles in orbit and gather environmental data has been conclusively demonstrated.

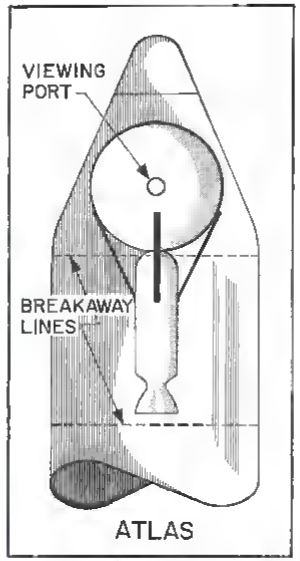
Funding Problems

Estimate is that to carry out the preoperational and test phases leading to operational status perhaps 10 times as much money may be required as had been allocated to support Pied Piper by last October, reported to be about $12 million.

Contending for funds with Pied Piper in the reconnaissance satellite category are Army's proposals for two television equipped vehicles of approximately 300 lb. and 700 lb.—considerably less than the 1 to 1½ ton weight projected for the orbiting satellite in the Pied Piper system.

Army Vehicles

Each of the Army vehicles would be fitted with one or possibly two television cameras feeding information to tape recorders for storage until the satellite



PROBABLE staging of Atlas and solid engine which will launch Pied Piper satellites

orbited within range of a ground station. Data then would be transmitted to the ground at very high speed for immediate use or future playback.

Selection of either Army reconnaissance satellite system or Air Force's Pied Piper satellite for operational use could be dictated by inter-service considerations and many other factors. But USAF's system might be favored because of its earlier concept and established program. Lockheed won the Pied Piper reconnaissance satellite competition in 1956 and became systems manager when the program was made firm in late summer of 1957.

Pied Piper, with its picture taking capability — versions could be equipped with optical or TV camera, infrared scanner or radar—might give rise to international protests against mapping a country's terrain from the sky above it. Defense conceivably could be that the great altitude of Pied Piper reconnaissance satellite permits it to map terrain from a point in the sky not over the protesting country's land.

While international ramifications of military satellite reconnaissance have not been widely discussed, considerable thought is being given to feasibility of jamming and defensive-retaliation against an earth orbiting reconnaissance satellite.

Perhaps the question of legality may never be raised because space travel,

which apparently could not be curtailed, could in its various phases give a view of all parts of earth. Even more likely possibility is the satellite stalemate that would result if both East and West established reconnaissance satellites in orbit before legal questions were answered.

With added support—particularly to speed up testing program, including initial firings to prove out propulsion combinations and operation of components while airborne—Pied Piper satellite probably will not be readied for an operational shoot before 1960, although one official projection specifies this capability by spring of 1959.

Manned reconnaissance satellite included in original planning for Pied Piper is likely to get less emphasis now that the man-in-space effort (AW April 7, p. 26) is underway. This program envisions orbiting man-carrying capsules.

Programs will be closely coordinated, and one of the final versions of the man-carrying capsule satellites for the man-in-space program might embody reconnaissance features developed for and proved in Pied Piper orbiting vehicle.

Altitude Compromise

Orbiting altitude for Pied Piper probably will be a compromise between relatively low heights required for reasonable results in scanning and higher altitudes conducive to longer orbiting periods because of less dense atmosphere.

While initial projections fixed this orbiting altitude somewhere between 300 and 1,000 mi., it is believed that an effort will be made to maintain the orbit at the lower end of this spread. Dangerous radiation band discovered by other satellite flights also will affect selection of the altitude for manned capsules.

Basic configuration of Convair's Atlas intercontinental ballistic missile is targeted as the booster to launch Pied Piper satellites. Second stage power plant, according to original planning was to be a liquid propellant rocket motor but solid propellant unit probably will be chosen to place satellite into orbit, and will be checked out in the test phase.

Test vehicles intended to evaluate components won't await readiness of Atlas as a completely proven and available booster.

Douglas Thor intermediate range ballistic missile will be drafted as the booster for initial test phases because it will be relatively proven, available and comparatively inexpensive.

Second stage for tests will be a solid propellant rocket which could be drawn from Aerojet General developments for

the Polaris IRBM or from Thiokol Chemical Co.'s developments in the field of larger solids. Polaris solid would seem to be favored because of Lockheed's relation to Polaris as systems manager and its familiarity with propulsion development for this program.

Other solid developments from Air Force's Minuteman program also could be used with Pied Piper test shots doubling in service as proving vehicles for these solid units.

Probably no single Pied Piper reconnaissance vehicle will incorporate more than one type of sensor for mapping—optical, infrared, or radar—because of payload restrictions and complexity of multiple scanning systems. This means that initial program will evaluate the different mapping systems with a series of separate vehicles to determine which offers the greatest return in reliability and definition of ground installations.

Still changing concepts for reconnaissance satellites may eventually call for several in different orbits at the same time, possibly with one serving to relay information from the others to the ground.

To be of value in a military sense, information generated by the surveillance systems will have to be fast and direct. Problems will include perfection of data links to send information to receiving stations on the ground for handling and translating. Special studies are underway relating to requirements and accuracies associated with interpretation and processing of data obtained from various types of scanners.

A far-reaching scheme under study by one company for applications to a reconnaissance vehicle concerns data processing and evaluation system which would permit pre-selected types of data to be transmitted to ground receiving station, eliminating the considerable mass of non-essential intelligence collected during surveillance. Applied to a system such as Pied Piper, this scheme would allow very discriminating scanning to facilitate interpretation, plus initiation of fast responsive action, if required.

One important scientific category likely to be opened by successful completion of the Pied Piper project is more precise determination of factors associated with controlling weather. This knowledge could have vast strategic implications, and probably will be broadened considerably. Results will be channeled to civilian agencies for resolution of problems relating to long range weather forecasting.

Another scientific extension of Pied Piper envisioned by industry researchers is its utilization as an astronomical tool for observing the firmament, unhampered by atmosphere phenomena.

Need for this type of study was

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voiced recently by Dr Hugh L Dryden director of National Advisory Committee for Aeronautics which would become nucleus of National Aeronautics and Space Agency under pending legislation Dr Dryden declared that NASA project favored for quick action would be development of satellite capable of carrying in orbit a telescope and auxiliary television equipment required to transmit to earth pictures taken through the scope It would be possible, he said, to construct a telescope of useful size together with supporting equipment to be carried in an orbiting satellite weighing approximately a ton Ability to observe stars and galaxies from space, where there would be no distortion caused by earth's atmosphere would permit gathering of a wealth of new information about the universe Dryden said

Observers close to the satellite picture feel that a version of Pied Piper if successful probably would be diverted for this type of service because relatively inexpensive modification could fit it for this role

Stabilization Problem

Stabilization will be a considerable problem with reconnaissance satellites Pieper orientation of the vehicle as it hurtles along its orbit will be extremely important if its scanner is to view the ground according to pre-selected plan and relay specific information This will involve precise position control equipment and demand on the vehicle's power source

In its recent annual report, Lockheed referred to a statement by Maj Gen Bernard A Schriever commander of Air Research and Development Commands Ballistic Missile Division that the reconnaissance satellite system will include a recoverable capsule In addition to the salvage capability itself goal obviously would be to bring down the capsule in an area from which it would be feasible to recover it and its expensive equipment

In addition to weight penalty of a returnable capsule which either cuts down other payload factors or increases the thrust requirement recovery features introduce requirements for more space and additional complication of equipment, such as retrorockets and parachute systems and activation devices

Some observers say it might be more expedient to project the system initially as a non-recoverable satellite and add the recoverable feature later They also expect Air Research and Development Command's man-in space program to develop recovery techniques that could be funneled into a recoverable unmanned or manned version of Pied Piper ■

SATURN and its ring system taken with 100 inch telescope at Mt. Wilson Palomar Observatories.

IGY Research Into Space Continues

By Michael Yaffee

Neither the launching of the 2,925-lb. Soviet earth satellite nor the preliminary results from our own satellite experiments has in any way altered the program for continuing research in outer space prepared by the Earth Satellite Panel of the U.S. National Committee for the International Geophysical Year, according to panel chairman Dr. Richard W. Porter.

Formally titled "Basic Objectives of a Continuing Program of Scientific Research in Outer Space," the report was distributed to administration, congressional and military leaders last February, after panel members had carefully reviewed the report themselves for a year. It is intended as a guide for a long term program of space exploration, a program that would be a continuation of, and go well beyond, the comparatively limited agenda of the current IGY program.

At present copies of the report are still circulating throughout the government and "getting thoughtful consideration." The report was available to the President's Science Advisory Committee, headed by Dr James R Killian Jr and its influence was obvious in their study "Introduction to Outer Space" released the following month

Basis of Planning

In all likelihood the satellite panel presentation will be the basis of planning the geophysical part of the future space work to be undertaken by the new civilian space agency when it comes into being There is little point in talking of implementing this program Dr Porter says, when there is not yet an implementing agency But if nothing else he adds the launching of the latest Soviet earth satellite does point up the necessity of getting started with this program as soon as possible

The report mentions no cost figures and stresses throughout the search for basic knowledge "Although there will be inevitable benefits of a very practical nature from such a program, the basic goal of this exploration must be the quest of knowledge about our solar system and the universe beyond" The development of the program starts with the role of sounding rockets progresses through earth satellite experiments, lunar investigations planetary and interplanetary exploration and concludes with manned space flight The bulk of the program is given over to satellite experiments

"Even when the technology of space flight has progressed far beyond the ability to put satellites in orbit and vehicles are being directed on heliocentric and interplanetary missions," the presentation points out, "the earth satellite will surely continue to be a base for fruitful observations" Now, however, is when satellite-based experiments can be most fruitful due to the almost complete lack of prior direct knowledge

In formulating their program, members of the Earth Satellite Panel assumed that the technology of space flight will develop gradually—the 1½ ton Russian satellite notwithstanding (The Russian work, to date at least, has produced no surprise among panel members according to Dr Porter) Therefore they state, the payloads and the distances traveled will be relatively small at first, and the scientific experiments and observations that go along with them will be correspondingly modest in the early stages

Accordingly panel members proposed to divide the satellite experiments into two groups First will come the "light weight satellite experiments' which can be carried out in Vanguard type satellites provided that the payload capability of these vehicles can be pushed to 50 or 75 lb. and assuming that there will be a wider choice of orbits than now allowed under the IGY program Later will be the more elaborate "advanced satellite experiments" which will culminate in manned satellites The experiments in the second group will require, among other things larger payloads, stable platforms high transmission power, large information bandwidth large auxiliary power sources, and recovery of packages

Satellite Experiments

In the first group the members of the Earth Satellite Panel have included the following experiments

• Creation of visible objects Among the many things scientists want to know more about are air density at high altitudes, size and shape of the earth, ion density and lunar mass Much can be learned about these unknowns through precise determinations

of satellite orbits. And optical tracking as opposed to present radio techniques is the more accurate method of determining orbits.

Because of the limitations of present optical equipment it becomes necessary to make the satellites more easily visible. There are a number of ways to do this. The first one to be used will probably be a large balloon, now under development at the National Advisory Committee for Aeronautics. Made of an aluminized plastic the balloon will be carried by a small satellite and automatically inflated upon release from the carrier. An alternative which the Russians suggested they would use, is a flashing light on the satellite itself.

• **Total atmospheric** thermal and visible radiation measurements. The purpose of these measurements according to the report, is to determine the radiational heat budget of the earth and atmosphere in order to learn more about the general circulation of the atmosphere. Radiation fluxes can be sampled by a set of omnidirectional bolometers and such a scheme is already scheduled for one of the IGY satellites.

• **Mapping of the cloud cover.** By scanning the earth's surface with photocells, a satellite can get a picture of cloud patterns over a large area. This will throw light on the way in which storm systems start and develop, the satellite scientists say.

• **Mapping of the night airglow** and aurorae. This experiment will be somewhat similar to the preceding one and would also be important to meteorological research.

• **Time fluctuations** of solar ultraviolet and X radiation. The idea here, according to the report, is to monitor these solar wavelengths over a long period, say for a year, for the purpose of correlating the ultraviolet and X ray intensity time curve with weather, radio propagation, the ionosphere, airglow, winds, and so forth. A start on this work is being made with IGY satellites containing instruments such as a photon counter which responds only to Lyman alpha radiation.

• **Distribution of hydrogen** in space. The same ionization chamber used to study solar Lyman alpha radiation can also be used to determine the density of hydrogen in space, "a subject of much interest and speculation."

• **Survey of celestial** sources in the far ultraviolet. The picture of stellar magnitudes in the far ultraviolet appears to be different from that in the visible and this picture can be more fully developed with the aid of a satellite.

• **Extragalactic light.** Satellite investigation of extragalactic light would, among other things, help test the hypothesis of the expanding universe.

Panel Members

Members of the Technical Panel on the Earth Satellite Program, U. S. National Committee for the IGY National Academy of Sciences are as follows Richard W Porter chairman G M Clemence Michael Ference, Jr Joseph Kaplan Homer E Newell, Jr., Hugh Odishaw W H Pickering J G Reid, A H Shapley, Athelstan F Spilhaus, James A. Van Allen Fred L Whipple.

Other ICY groups who helped in the planning of this program are Working Group on Internal Instrumentation James A Van Allen chairman, Working Group on Tracking and Computation. W H Pickering, chairman, Working Group on Satellite Ionosphere Measurements A H Shapley, (chairman)

based on the so-called red shift

■ **Cosmic ray observations** Fairly extensive investigations in this area are scheduled for IGY satellites, some of which have already been flown But cosmic ray experimentation is like writing a book, Dr Porter says, you start one chapter and this leads to another and it keeps right on going

■ **Primary auroral particles** The use of satellites to observe these particles (protons electrons, heavy particles, etc) will enable scientists to correlate variations in their intensity with solar activity to an extent presently impossible with any other means Also this auroral work is closely related to investigations of the geomagnetic field

"Indeed, it would be desirable, in order to obtain mutually supporting sets of data, to have two satellites aloft simultaneously—one carrying a magnetometer and the other carrying auroral radiation detectors. Eventually it may be possible to have a single satellite carry both types of apparatus."

● **Micrometeorites** Investigations in this area are designed to answer the many questions that the IGY satellite experiments are unable to cover because of limited equipment and operational time Some of these anticipated questionmarks, for example, are How are these particles related to visible meteor showers? What are the fluctuations in total intensity?

■ **Magnetic field** As much as 7% of the variations in the earth's magnetic field are due to a variety of current systems in the ionosphere and above and cannot be accurately measured by ground-level surveys or by aerial reconnaissance. "The ideal approach would be to use rockets and satellites in combination, thereby obtaining a more complete map of the geomagnetic field in three dimensions and in time"

● **Ionospheric observations** It is certain, the report states that valuable ionospheric experiments can be made by means of satellite radio transmissions.

By using the satellite as a known source of radiation, for example, it will be possible to measure certain aspects of the fine structure of the ionosphere such as the horizontal inhomogeneities in the E- and F-regions.

■ **Biological experiments** Provision for this work is made in the first group of satellite experiments because the satellite scientists believe they should be started at the earliest opportunity "since they will be crucial to the eventual attainment of manned space flight"

Balloon and rocket flights of living organisms have been underway for some time, and the U S IGY satellite program includes experimentation with yeast samples But these programs will have to be greatly expanded primarily in order to learn more about the effects of weightlessness At the same time the Earth Satellite Panel doesn't believe that satellite studies of radiation effects on biological specimens will prove very rewarding

Advanced Satellite Experiments

Later on as the satellites get larger, it will undoubtedly be possible to place men themselves in the vehicles The value of such an experiment is still being debated But man will inevitably venture into outer space sooner or later say the scientists "Whether the presence of a man in the vehicle will contribute to our knowledge of the universe is beside the point Such an achievement should, perhaps be considered as an end in itself—the ultimate biological experiment"

On a somewhat more immediate basis are a number of fairly complicated and more scientifically rewarding experiments that the panel has planned for its first advanced satellites Among these are the following

■ **Selective and directional thermal radiation measurements** The idea is to obtain a complete record of thermal radiation for an entire satellite circuit in order to map the effective temperature of different layers high in the atmosphere This could be the key to the development of a physical basis for long-range weather prediction the report states

■ **Selective and directional ultraviolet and X-ray measurements** With sufficient payload available the panel feels that it will be possible and desirable to make more refined spectroscopic surveys of the earth's atmosphere in the far ultraviolet

● **Astronomical spectrograms** With a spectrograph mounted in a satellite astronomers will be able to study the sun, planets and stars in far more detail than now possible Techniques for recovering the spectrographic film cap

sule have been proposed and are considered feasible.

• **Ultraviolet photographs** of the sun. Such photographs should prove an important aid to understanding solar activity, much of which is associated with the emission of ultraviolet radiation. As in the case of the astronomical spectograms, the film would be recovered, or a possible alternative might be to use photoelectronic recording and telemetering of the observations, particularly if a fairly continuous picture is desired.

• **Planetary spectrograms.** The purpose of this experiment—a variation of the one on ultraviolet and X-ray measurement—is to measure the spectra of the various planets in the ultraviolet and infrared in order to determine more precisely the compositions of the planetary atmospheres.

• **An experimental test of the general theory of relativity.** By flying a super accurate "atomic clock" in a satellite and comparing it to a similar timepiece on the ground, it should be possible to test the general theory of relativity, which in effect says there will be a difference in the running rate of the two clocks because of the known difference of gravitational potential.

• **Solar (cosmic) radio noise** in the high-frequency and low frequency spectrum. Because a satellite would not suffer from ionosphere absorption, it could be used to observe the radio noise from the sun and beyond which is not able to push through the ionosphere.

• **Collection of micrometeorite samples.** This work, already underway to a limited degree in balloons, will help answer a number of questions concerning such things as the relative abundance of elements in the solar system and the scattering effect of this dust, observed as the zodiacal light.

The last and ultimate satellite experiments noted in the report are the ones with men in them, mentioned above. Next comes the moon.

As part of its long range space research program, the Earth Satellite Panel proposes to explore the moon both by flying satellites around it and by landing instruments on its surface.

In the report, priority is given to those experiments which would provide information about the moon as a whole. These include measurement of lunar mass and gravity, direct measurement of the lunar magnetic field, and measurement of the lunar atmosphere. The last experiment is probably the only one that will require a landing on the moon, it says. (Impact velocity is calculated to be about 9,000 fps. for a vehicle taking two to three days for the trip.)

In the group of localized experiments, which would require landings of instrument packages on the moon's surface, are seismic and microseismic observations of the lunar crust and observations at the point of impact, the latter to include measurements of surface and subsurface temperatures, surface hardness, and chemical composition of the surface material.

Ultimately, the report states, there will be manned vehicles capable of landing on the moon. And in the context of the program as described by the satellite scientists, the investigation of the moon is "but a step to the investigation of the planets."

Interplanetary Investigations

Mars and Venus will probably be the first planets to be explored because they are the closest and the most intriguing. And, once the guidance and propulsion problems have been licked, the report says, it should be a fairly straightforward proposition landing instruments on these planets because the problems are practically the same as those involved in placing like packages on the earth's surface.

Landing on small and sun scorched Mercury, the panel believes, will involve many of the same problems as landing on our own moon. The large outer planets, on the other hand, pose altogether different problems. There may be no such thing as 'landing' on their inner cores, which very possibly are nowhere solid but may consist of a liquid center merging with a deep gaseous envelope. One might, instead, design a vehicle which would enter the atmosphere of such a planet and then settle to a certain density level, where it would float, like an inextensible balloon."

Man will eventually follow his instruments into space. Right now, this act appears difficult to justify logically, since instruments can be designed to do all the space research and reporting that is desired. Moreover, these instruments can be and will be abandoned without any misgivings.

It is very possible, of course, that these instruments will reach a level of largeness and complexity which would justify the use of a human being for reasons of efficiency, reliability and resourcefulness. More pertinent is the fact that man will certainly possess the capability to go into space, the Earth Satellite Panel declares, and it is hard to conceive of him stopping short when such a tempting goal is within reach—regardless of whether it is necessary or not.

"With man's first venture into outer space, a new program of research and exploration will begin. The program described above will therefore be the prelude to the drama to follow." ■

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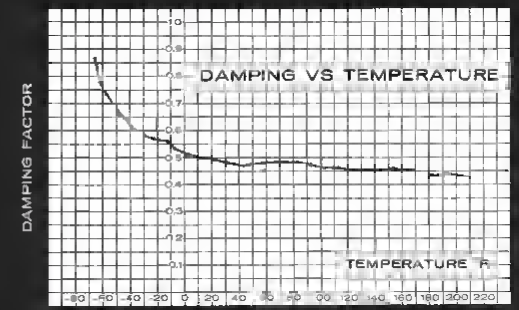

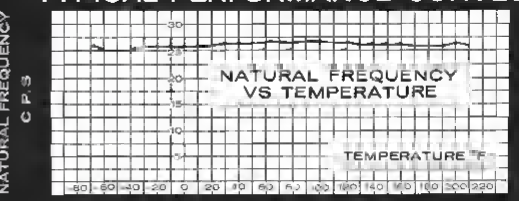

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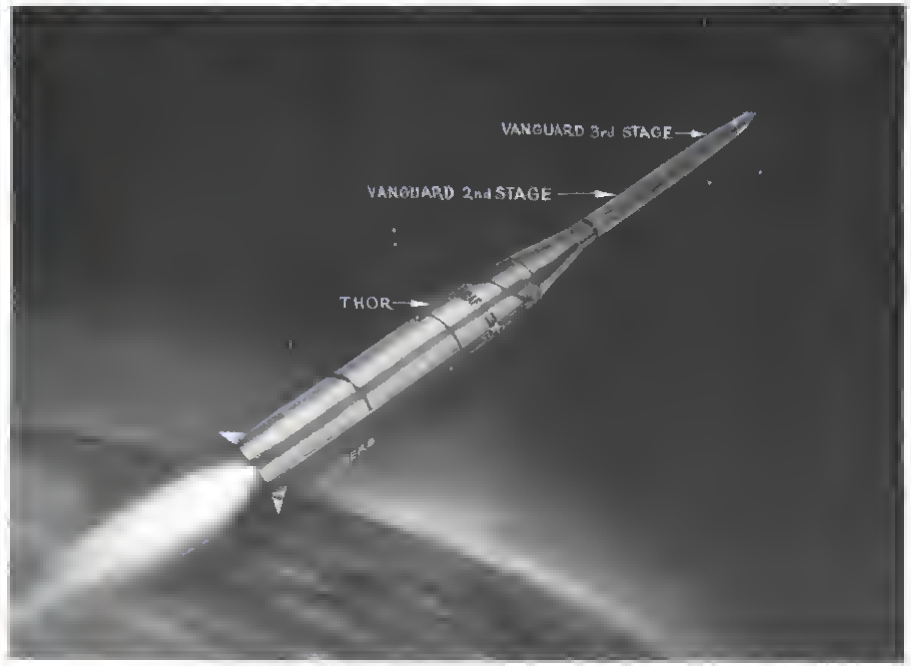
CONVAIR Atlas complex at Cape Canaveral, Fla., shows vast amount of facilities that support test firings.

Research Facilities



POSSIBLE configuration of USAF's moon probes is a Thor booster topped by both upper stages of the Vanguard satellite vehicle.

Probes Will Explore Cislunar Space

By Irving Stone

Lunar probes to be launched by the Air Force and Army will mark the first long reach into space and set the stage for manned exploration of the moon.

Both Air Research and Development Command's Ballistic Missile Division and Army's Ballistic Missile Agency will attempt to fire their first moon vehicles before the end of this year. Both programs are under the authority and direction of the Advanced Research Projects Agency. BMD has been assigned three moon probe shots, and ABMA probably will launch two. Total funding through Fiscal 1959 is $80.2 million. Vehicles will encompass these configurations:

● **ABMA's lunar probes** will be known as Juno II. They probably will differ from the Jupiter-C used to orbit Explorer satellites only in that Jupiter intermediate range ballistic missile booster will be substituted for Redstone booster. Juno II configuration would use a Jupiter IRBM first stage, a cluster of 11 scaled, solid propellant Sergeants as the second stage surrounding a cluster of three Sergeants as the third stage, surrounding a single Sergeant as final stage.

● **BMD's lunar probes** will use Douglas Thor intermediate range ballistic missile as a booster coupled with Aerojet General's modified liquid propellant second stage Vanguard engine, plus a third stage now tentatively scheduled to be Grand Central Rocket Co.'s modified third stage Vanguard solid propellant rocket. Another possibility for the third stage is a fluorine hydrazine engine under study at National Advisory Committee for Aeronautics' Lewis Flight Propulsion Laboratory, Cleveland, Ohio.

While the Thor-second stage Vanguard combination will be checked out in a series of at least three shoots under Project Able—and in three more under Project Bravo, the follow up and extension of Able firings—there is no plan at present to test check the Thor-Vanguard second stage-Vanguard third stage combination.

BMD plans to "go for broke" on the first moon probe shot. If the missile attains the "vicinity" of the moon (useful data might be obtained as far as 10,000 mi. away) there are four distinct possibilities. It could:

● **Travel on out** past the moon.

● **Circumnavigate** the moon and return to earth's atmosphere where the probe payload would burn up. This trajectory probably would depend on the moon's gravitational pull to turn the vehicle into the proper path for return toward earth.

● **Come close enough** to the moon to be drawn into its gravitational field and by extra thrust and proper timing become a lunar satellite.

● **Impact on the moon.** Efforts will be made to avoid this possibility, since a

probe passing behind the moon or orbiting it could produce infinitely more data on the lunar environment.

All three of BMD's moon probes will carry the same payload weight which will be about 30 lb., but each will carry different instrumentation in order to cover a substantial data gathering range. Intervals between BMD's moon shots will be determined by the time required for reduction of data from and modifications indicated by the previous launching.

Original launch date for the BMD probe was Aug. 16, but this may be delayed. A tracking station is being built in Hawaii. Probe will use the Minitrack frequency of 108 mc.

ABMA's Approach

It is probable that ABMA's general approach for its moon shots will be similar to BMD's, since the scientific data each could gather would be in same general categories.

Probes would gather information on the moon's surface through a mechanical ground scanning device scheduled for development at Naval Ordnance Test Station, Inyokern, Calif. Resulting picture will not be as definitive as a television presentation since simplicity of equipment will be dictated by payload limitations. Miscellaneous measurements with the probe might determine:

- **Existence of lunar "atmosphere,"** its composition and density—if one exists.
- **Temperature distribution** over the moon's surface.
- **Ion density** in the lunar atmosphere and in cislunar space.
- **Characteristics of the moon's own** magnetic field, its distributions and time variations.
- **Amount of radioactivity** reflected from moon's surface.
- **Meteorite impact on vehicle** between earth and moon.

There is a tentative plan for a look at the far side of the moon. Probably the same type of terrain exists, but some specific differences might be startling. Photos of the moon's far side would be taken with a Land camera in an ABMA probe and transmitted to earth electrically.

There is little doubt that the first BMD and ABMA moon probes—even though they will return scientific data—are intended primarily to contribute to U.S. prestige and will offer little military value.

This viewpoint is fully understood by a broad group of scientists and military personnel, who point out that military support for space exploration is justified at this stage simply because it is being carried out in a scientific pattern. Value of these lunar probes as well as earth satellites, must be exploited quickly because they are basic experiment vehicles which must supply fundamental knowledge on which further exploration of space will depend.

It also is clear that Russia will accelerate its effort with regard to lunar experiments as much and possibly more than it did with its earth satellite projects in this opening phase of space exploration.

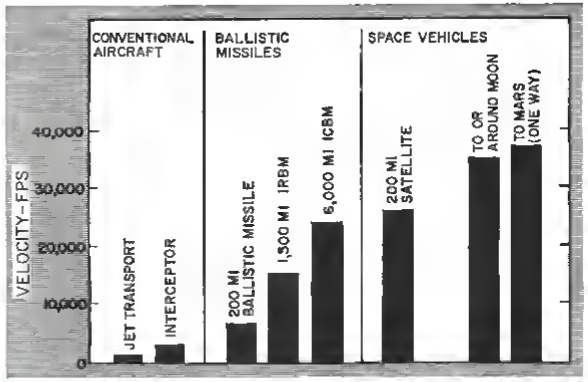
It is impossible to foresee both scientists and military personnel contend what the strategic condition may be in the next 15-20 years. Hence it is mandatory that preparation be done with military support feeding the scientific hopper of space. At this point it is claimed, the overall philosophy of space exploration becomes a matter of emphasizing what basically is required, as distinguished from what can be done. In this respect lunar probes are considered to be a necessity as opening wedges in the space regime, rather than an isolated exercise.

LAST quarter moon in 100-in. composite photo from Mt. Wilson-Palomar Observatories.

Probably the most critical factor in the matter of initial lunar probes and follow-up lunar experiments, including the ability to propel manned capsules for circumnavigation and eventual landings is propulsion potential.

Considerably before lunar probes were actively pushed under the present programs, vehicles were proposed for moon vicinity travels using off-the-shelf propulsion units to avoid dependence on ballistic missile hardware and minimize project costs.

One of these, Farside II, was conceived and formulated during Farside Phase I studies by Aeronutronic Systems, Inc., under sponsorship of the Directorate of Advanced Studies, Air Force Office of Scientific Research. It contemplates a vehicle for placing a total payload of about 25 lb. in the vicinity of the moon, not necessarily to impact on it. Solid propulsion staging includes five steps involving various



COMPARISON of minimum velocity requirements by A. F. Donovan of Ramo Wooldridge's Space Technology Laboratories shows that trip to or around moon requires about 40% more velocity than ICBM, indicates how applicable they are to space travel.

uses of Thiokol Sergeants and Grand Central Rocket Co. third stage Vanguard units. This proposal has not yet been approved by ARDC.

Another scheme using some off-the-shelf solid propellant units is Aerojet-General Corp.'s Aerobee M lunar vehicle. This five stage vehicle combines Aerojet Seniors, Juniors and other solid units.

In contrast to this approach, particularly in BMD, the trend naturally is to consider using ballistic missile boosters for lunar probe vehicles—Thor IRBM plus other stages for a vehicle with a relatively light payload, and probably the Convair Atlas and Martin Titan plus other stages for heavier payloads to do the follow up jobs undoubtedly being contemplated now.

It is estimated that an ICBM with added stages might be used to take a man around the moon—depending on how weight of the capsule could be trimmed—or to carry a very small payload out to Mars.

Off-the-Shelf Hardware

Experts close to the ballistic missile activity strongly advocate use of existing ballistic missile hardware for early space exploration, such as lunar probes and earth satellites rather than to undertake new developments for this work. They point out that there is a general lack of appreciation of just how far the ballistic missile program has progressed in a relatively short time and the great contribution it has made to almost every phase of engineering and science associated with aeronautics—contributions that will be carried over to out-of-atmosphere operations.

Opinion is that literally hundreds of experiments, including lunar probes, could be accomplished within the next five to ten years with various combinations of Atlas, Titan, Thor and Jupiter as first stage boosters, carrying a wide variety of electronic and photographic payloads.

Utilizing existing ballistic missile hardware problem is not one of inventing space missions but one of being wise enough to select the "right" missions. This approach involves discretion in mission choice—such as circumnavigating or orbiting the moon instead of impacting on it, even if the Russians, for example, already had achieved an impact.

Because of the numerous possibilities inherent in early space exploration, no single demonstration is going to determine which country is leading in technical accomplishments. It can safely be assumed that Air Force and Army planners will be extremely selective in projecting future missions—in the lunar region or any other category of space exploration.

Refinements in present ballistic missile hardware also can pay big dividends in early capability for launching probes and other space ventures, in contrast to explorations that may require completely new engineering. New boosters or other big technical advances required for very large payloads or very high speeds may involve six or seven years of development time before they become usable operationally.

Follow-up of initial moon probes with vehicles carrying payloads capable of more extensive experiments could contribute information that would facilitate lunar landing attempts when that phase is approached in progressive steps. This would include the most feasible areas for putting down instrument carrying packages, for landing and take off of manned vehicles, and for detailed

surface investigations within the limits of projected ship-over times.

Experiments using moon impacts have been suggested by Dr. John L. Barnes, Systems Corp. of America. For material capture, a shaped charge explosive delivered to a region selected on the basis of earlier studies would be detonated at a specified depth. Several moon satellites, timed to arrive when the surface material has been propelled to an adequate altitude above the moon's surface, would collect samples of this material, analyze them by automatic equipment and telemeter the results to an earth station. Location of a lunar mining operation on the moon's face would be mapped by telescopes on earth. Lunar television satellite would pick up mining on the moon's far side.

For a seismic wave transmission experiment, several moon missiles would deliver instrumented packages to the lunar surface. As each package arrived, explosion of a magnesium-oxygen charge would be observed through earth telescopes and lunar satellite TV pickups, spotting the approximate location of each instrument package on lunar surface.

Included in the package would be a seismic recorder coupled to a telemeter transmitter. A sizeable explosive charge with proper delay time would be delivered to a selected region of lunar surface by moon missile and detonated at the prescribed depth. Explosion would be

Moon Highlights

- Average distance from earth is 238,857 mi.
- Diameter is 2,160 mi., more than one-fourth that of the earth's 7,927 mi., but earth has 81 times the mass of the moon.
- Gravity is one-sixth that of earth; escape velocity is 1.5 mi. per sec.
- Time to circle earth equals time moon requires to make complete turn on own axis. Thus it presents same face to earth. Slight wobble in moon's motion permits earth observers to see total of 59% of lunar surface over period of time.
- Estimates of lunar surface dust range from depth of few inches to miles.
- During 15-day period of sunlight, dust top layer temperature ranges as high as 214F, while lunar night brings temperature to 243F below zero. However, temperature below top layer of dust is constant minus 40F.
- Lunar mountains range as high as approximately 6 mi.
- More than 30,000 craters, extending from one-half to 150 mi. in diameter, some approximately 4 mi. deep, pock the lunar surface.
- Lunar atmosphere may contain very small amounts of krypton, xenon and other heavy gases.

mapped by earth telescopes and lunar satellite TV pickups, and propagation of moonquake waves would be monitored by pre-placed lunar sensors and returned to earth stations. Lunar orbiting vehicles also might relay this information back to earth.

Another impact study for gathering data on moon surface characteristics has been made by Rand Corp. Boosted by an Atlas ICBM and other stages, the Rand lunar test instrument carrier would penetrate the moon's surface with a pointed nose.

Telemetered data might afford invaluable information on the depth of the moon's surface dust or fragment deposits and related physical features to aid in planning future manned landings. Atlas burning phase guidance could control nozzle position for angularity and speed at cutoff to within one foot per second. As the moon is approached, retrorockets would be activated for probe to attain calculated entry speed, to avoid destruction of instrumentation on impact, and rockets would be gimbal-controlled to insure proper entry angle.

Dust Problem

Subject of dust on surface of the moon has prompted considerable discussion and is more pertinent now because of the likelihood of lunar landings within time scales which can be estimated broadly today.

Thomas Gold, professor of astronautics at the Harvard College Observatory, believes that at a depth of a few hundred feet, moon material probably would be quite solid. Top few feet might be extremely loose and more treacherous than quicksand. Conditions that generally tend to compact things on earth are absent on the moon and much more loosely packed material might maintain itself for long periods. If deep, loose deposits of dust are a common feature of the moon, a substantial bomb exploded in a place where the debris would be illuminated by sunlight and visible from the earth against a dark background could prove this point.

Moon's surface is subjected to bombardment by meteoritic material and corpuscular radiation (protons) and to a slow rain of dust, molecules, atoms and ions as a consequence of the meteoritic bombardment. These processes, coupled with solar radiation, will tend to cement the dust into a weak, semi-porous matrix and no appreciable quantity of dust will be found on the moon's surface, according to Fred L. Whipple, director of the Smithsonian Astrophysical Observatory and astronomy professor at Harvard College Observatory.

Surface material should not blow badly in a rocket jet and should be suffi-

ciently rigid for support of the normal structures and operations required in a lunar expedition, Whipple believes. For transport of great weights and requirements of expeditionary travel, greatest hazard should be crevasses, with the very real possibility of unsubstantial roofing over gaseous pockets in the lava flows of the lunar "seas," Whipple says.

Moon impact trajectory scheme envisioned by Aeronutronic Systems Inc. requires little or no velocity control but requires precise control of thrust direction. The rocket would proceed from earth along a ballistic trajectory and reach the moon's area at a time determined by the initial velocity. A series of these trajectories has been devised in which the distance that the moon moves in its orbit during the differential flight time between two neighboring trajectories, is just equal to the spacing of the trajectories. If lunar impact is achieved with one of the trajectories it also will be achieved by the neighboring trajectories in the series.

With this technique, tolerance to burnout velocity error is greater than 100 fps. This degree of velocity control is attainable with careful propellant loading in the final stages, and payload penalty normally associated with velocity control of a few feet per second (10 or 15 fps) can be avoided.

This technique requires initial design velocity that slightly exceeds escape velocity and a small payload penalty is introduced for additional propulsion required. Excess velocity over escape value is about 100 fps. In contrast to tolerance for velocity error, path angle (angle between local vertical and tangent to trajectory at burnout) must be controlled to within 0.2 deg.

Thermonuclear explosion also could verify impact, but some scientists feel that this device would not be feasible because of the contamination hazard, which would interfere with follow-up exploration.

Use of a dye marker to verify impact might be feasible if a sufficient quantity of fluorescence were introduced, but this would not be an easy task.

Ultimate goal of lunar investigations, the manned-vehicle landing, is on very slim ground at this stage of space technology, since a tremendous mass of data must be gathered and numerous critical techniques perfected before man can perform substantially useful functions in space.

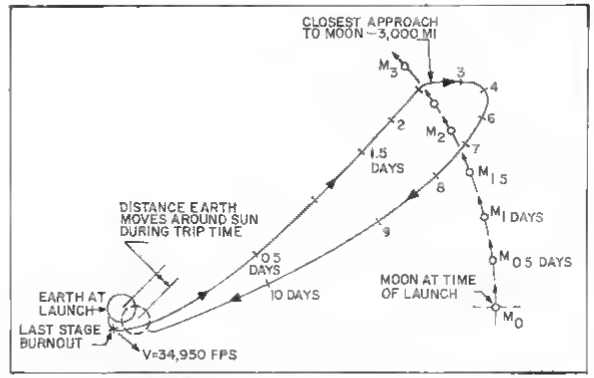
Hazards of the manned moon mission, wherein man will be required to perform various functions, is pointed up by comparison with the passive role man would play in a relatively simple, manned earth satellite.

Assuming that men land on the moon, the question of take-off capability for return to earth poses tremendous difficulties. Simple analogy is to consider the complicated countdown procedure for a ballistic missile at Cape Canaveral, and weigh this against capability of one man or a few men, on the surface of the moon, preparing for return to earth. Obviously, simplification will have been achieved within the time scale for manned landings on the moon, but take-off complexities probably will still be substantial. Highly reliable solid propellant rockets probably would be chosen for return thrust if landings were attempted in the foreseeable future, some experts say.

One scheme for verifications of a moon impact involves the use of 10 ft metalized balloons. Twelve of these balloons with their time and release mechanisms would weigh less than 20 lb. Illuminated by the sun, the reflecting balloon at lunar distances would appear as a 17th magnitude star visible in a 40 in. telescope. If a number of balloons were released along the trajectory, sunlight pressure would produce an acceleration that would separate balloons launched a day apart by 1,000 km.

To follow the vehicle's trajectory, the moon should be in the first or third quarter so that balloon dispersion is perpendicular to the line of sight. If the vehicle struck the moon, a number of the balloons also would strike. This would be established if those balloons on predicted impact trajectories no longer were observed after transit across the moon, and the remaining balloons were seen after transit.

Other impact verification schemes include optical and infra-red scanners which would determine angular size of the moon as an indication of proximity. These could be kept within payload limits of about 30 lb., with most of the weight being in power supply.



TRAJECTORY for initial flight around moon and return, calculated by A. T. Donovan, Ramo Wooldridge Space Technology Laboratories. After last stage burnout vehicle would be in free flight and use moon's gravitational field to cause it to turn back to earth.

Still another method is based on measurement of the moon's radioactivity. Scanning would not be necessary because radiation received by spherically symmetric counter arrangement is proportional to the solid angle subtended by the moon at the counter. Whatever the vehicle's orientation, the counter rate above background is proportional to the square of the distance to the moon.

Protection requirements, particularly for a lunar capsule, will be far more rigorous for the lunar venture than for an earth satellite experiment. This is pointed up in the simple aspect of earth-atmosphere re-entry speeds—25,000 fps for an earth satellite, against 35,000 fps for re-entry from a lunar trip.

Establishment of a lunar base undoubtedly would offer inestimable scientific advantages, such as:

• **Opportunity** to study all aspects of lunar surface which might lead to firm theory on formation of solar system.

• **Observation of earth's** global weather. This would be of tremendous value in commercial operations, and could have decisive military significance in furthering the ability to control weather over particular areas.

• **Astronomical platform** for optical and radio telescopes to supply precise information on solar system constituents and characteristics of other stars.

• **Mapping ability** from two or more positions on opposite sides of the moon to afford long base lines, gross features of the earth could be delineated accurately by telescope.

Cost and time estimates for putting a man on the moon and establishing a scientific-military base there vary widely. One estimate is 10 years and $1 billion for the first step, 20 years and $20 $50 billion for an operational base.

USAF Considers Test Vehicle Family

A program to create a family of basic vehicles for a broad variety of out-of-atmosphere research and testing that normally could be conducted only with expensive operational ballistic missile is being considered by Air Force.

Philosophy behind this concept—designated BMTS, for ballistic missile test systems—is that within the military services and other government agencies there are numerous requirements for research and test associated with ballistic missile components as well as other technical factors, which would not be economically feasible if each agency developed its own test vehicle. This gives rise to the demand for a family of "standardized" carriers to meet a multiplicity of requirements. Characteristics of these vehicles would emphasize:

- Flexibility for adaption to wide range of payload and altitude combinations.
- Relatively low cost.
- High reliability.

Four Phases

At this stage of planning, approximately four phases are envisioned for the program.

- **Phase I** contemplates a vehicle for lifting sizeable (several hundred pounds) payloads to moderate altitudes (several hundred miles). In this phase hundreds of vehicles may be involved to cover the broad area of research and test. This indicates a need for a relatively inexpensive configuration instead of the huge expenditure which would be involved if Thor or Jupiter IRBM boosters were used. Also, Thor and Jupiter IRBM vehicles probably would not be available in sufficient quantities to meet BMTS Phase I requirements.

Industry feeling is that, for Phase I, tooling available for off-the-shelf solids might be used with necessary modifications fed in to create both boosters and successive stages.

One example of a space vehicle fitting Phase I requirements might be cluster of Sergeants coupled in successive stages embodying clusters of even smaller rockets.

- **Phase II** would be an extension of Phase I, utilizing a vehicle affording much higher performance such as lifting payload of several hundred pounds to several thousand miles. This phase conceivably would require at least Thor or Jupiter as booster.
- **Phase III** essentially would be associated with lunar research and test, involving relatively small payloads with larger booster than in Phase II. Atlas or Titan is indicated as booster for this phase.
- **Phase IV** would comprise "lunar plus" capability, possibly for operations involving braking on approach to and landing on moon's surface and for research and test beyond lunar regime. This phase also would involve relatively small payloads but larger boosters than in Phase III.

Another approach to the overall program involves use of common payload and top rocket sections with use of increasingly larger boosters as research and testing phase requirements increase. Feeling among industry is that complete adherence to this approach, as well as to the latter phases of the four-step projected program, is inefficient because mass ratios (weight of stage at ignition to weight of stage at burnout) become unfavorable as larger boosters are used. For the latter phases of the BMTS program, opinion is that it might be more efficient to use a completely new vehicle design to match the specific needs of research and testing.

Program's Future Uncertain

Future of BMTS program is somewhat uncertain. Program primarily has been sponsored in the past by Air Research and Development Command but is not funded. It is likely that implementation of BMTS will have to await decision of Advanced Research Projects Agency, which already has advanced ideas to Air Force that modify the concept.

Main aspects of the program still to be determined, include:

- **Government agency** that will have cognizance of the program, probably ARDC's Ballistic Missile Division or Defense Department's new Advanced Research Projects Agency.
- **Whether all phases** envisioned for BMTS should be implemented or if just mutual vehicle configuration should be authorized.
- **If contracts** should be awarded on the basis of proposals which already have been made by some industry segments or whether awards will be based on new competitions.

ARDC Request

If BMTS is funded and the program implemented ARDC's Ballistic Missile Division probably will request that it be given overall management of the project even though it has not been a strong proponent for the program in the past. Its philosophy has been

BMTS vehicles would use missiles such as Thor Able re-entry and moon test rocket.

that the most important, and probably bulk of tests would he conducted more efficiently with the missile with which the test payload was associated–for example, that it would be most feasible to check a specific guidance system on the missile for which it is designed, rather than on a BMTS vehicle, since the test vehicle might not truly simulate the missile itself Wisdom of the contemplated BMTS program is questioned seriously by many in industry for this specific reason

Concept Requirements

However, there are numerous requirements under the BMTS concept which would not be directly associated with ballistic missile development and some segments of industry contend that the program would be amply justified in this respect Apparently question resolves itself as to whether the research and testing not directly associated with ballistic missile development would justify the creation of a family of specific missile configurations to carry out miscellaneous research and development as well as that directly concerned with ballistic missiles themselves

Because solid propellants are being looked upon with increasing favor for missile application, many in industry feel that the simplicity of these units their reliability, general ease of handling and smaller group of people required for preparation and firing might accelerate the adoption of solids particularly in the early phases, for a vehicle which could be used advantageously under the BMTS program BMD's Minuteman program, now being pushed energetically to create a simple and effective intermediate range ballistic missile, might possibly contribute a family of solid propellant configurations which could easily meet the demands of the BMTS program even for advanced stages

Research and Testing

Fields likely to be included in BMTS program of research and testing are

● **Ballistic missile components**, such as guidance and control systems, miscellaneous valves, fuel system and propulsion system pumps, nose cones, and warhead fusing for altitude detonation Propulsion system as such would not be checked in a BMTS vehicle

● **Human factors** Engineering tests could be performed on equipment for manned out of atmosphere vehicles medical experiments could be performed with small animals or with other living organisms

● **High altitude experiments** This would include heavy payload instrumentation fired to "reasonable" altitudes and probably lighter payloads to very high altitudes at very high speeds ■

New Test Tools Needed for Space Age

One of the best indications that manned hypersonic and orbital flight is near is the sharp reduction in transonic and supersonic testing in the U.S. during the past year.

The rather large number of big transonic and supersonic tunnels built by government agencies, aircraft firms and private research groups in recent years have not been receiving their expected utilization in the past 12 months or so.

Main reason is the cancellation of many of the supersonic aircraft projects that were under way two years ago and more advanced systems that are now under study. This rapid advance in feasible speeds for manned aircraft and the apparently unforeseen increase in their cost have left wind tunnel and research facility operators with two primary problems:

- Operating on the reduced revenue from present facilities and financing the new facilities needed to stay in business during the next 10 years.
- Deciding exactly what these new test facilities should be.

Modification Costs

The seriousness of the first question for most operators is typified by Cornell Aeronautical Laboratory's experience with its newly modified high speed tunnel. The modification alone cost $2.25 million. It permits testing of large models in the 8 x 8 ft. test section through the transonic range and up to about Mach 1.4.

During the first year of operation after this modification the tunnel was running at the somewhat outstanding utilization figure of about 5,000 hr. of testing time per year. This required a 24-hr. operation and rather large staff to handle the necessary model work, tunnel operation and data reduction. About one year ago this pace began to taper off.

The tunnel is now on a one-shift basis and is operating at about 1,000 to 1,200 testing hours per year with a reduced staff.

As the tunnel is being amortized over a six-year period at an expected rate of 2,000 hr. per year, some adjustments probably will be made in the amortization rate. The present low rate of utilization also affects the amount of money the laboratory has to apply toward new facilities.

This situation is almost universal and compared to 18 months ago, test time is easy to obtain in almost all supersonic tunnels in the U.S. The Southern California Cooperative Wind Tunnel, owned by several aircraft companies and operated by the California Institute of Technology, recently completed a major modification similar to one at Cornell Lab.

A large tunnel complex also was completed a short time ago at Air Research and Development Command's Arnold Engineering Development Center at Tullahoma, Tenn. These new tunnels plus new company-owned high-speed tunnels like those at Boeing, Convair and North American, and existing high speed facilities at National Advisory Committee for Aeronautics laboratories, Wright Air Development Center, and several universities leave the transonic and supersonic tunnel picture somewhat saturated.

Most of these tunnels are receiving a respectable amount of utilization but are not being run at maximum capacity. Some of the tests being conducted are of a basic nature and even though basic studies are useful, they probably would not be scheduled if more new design work was available.

While a substantial number of these transonic and supersonic tunnels probably will always be necessary, they seem to have been overbuilt generally. This recent miscalculation of testing requirements is giving those who must direct the construction and operation of test facilities more than the usual concern for the future.

At present no one seems certain of exact types of experimental equipment that will be necessary 10 years from now. Many industry officials indicate that space laboratories are needed, but they often are not clear about the details of such a laboratory.

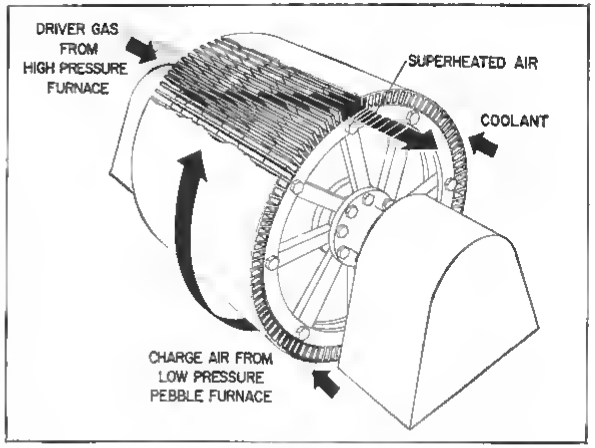
In addition, many available types of hypersonic and advanced environmental and structural facilities are relatively small and inexpensive compared to the larger supersonic facilities that have been built privately. This has lead to a "backyard" approach in many testing activities concerned with advanced flight problems.

This "backyard" approach is giving a large number of people a better understanding of high speed and high temperature problems, but it probably will not be adequate to see the industry through all hypersonic aerodynamic, structural and environmental tests.

The main problem of the private, not-for-profit and government testing groups is to select the types of larger, more expensive facilities that can fill the holes left by the smaller equipment, which cannot obtain data with realistic scale effects.

Most of the larger facilities that have been considered have inherent limitations also, and it is again problematical as to how long they will be commercially useful.

Much of the military and industry thinking about "space" laboratories concerns facilities that will give realistic conditions for studying radiation ef-



CAL wave superheater provides test periods measured in minutes at high Mach numbers.

Experimental Techniques for Hypersonic Research

EXPERIMENTAL TECHNIQUE	EXAMPLES OF RESEARCH PROBLEMS FOR WHICH TECHNIQUE IS SUITABLE	SIMULATION CAPABILITIES AND LIMITATIONS
[illegible]-propelled models	Heat transfer and skin friction Boundary-layer transition Cooling methods Characteristics of materials and structures at high temperatures and heating rates Aircraft configuration lift, drag and stability, including dynamic behavior	Correct flight enthalpy, Mach number, Reynolds number Limitations include relatively high cost and inability to observe phenomena taking place at close range
Ballistic ranges	Skin friction and drag Boundary-layer transition Flow characteristics including shock-wave-boundary-layer interaction Possibility of studying heat transfer and dynamic flight behavior of models with development techniques and instrumentation	Correct flight enthalpy, Mach number, and Reynolds number Principal limitation is the difficulty of making accurate measurements of more than a few relatively simple quantities
Shock tubes and shock tube wind tunnels	Properties of air at high temperatures Relaxation effects Heat-transfer and boundary layer phenomena for same conditions Flow configurations, pressure distribution	Correct enthalpy and Reynolds number with low Mach number or correct enthalpy and Mach number with low Reynolds number. Millisecond testing times
Intermittent tunnels of AEDC 'Hotshot' type	Similar to those suitable for shock-tube study	Correct enthalpy and Reynolds numbers for Mach numbers of about 15 Short testing times
'Gun' hypersonic tunnels with long testing times; heating accomplished by (a) Combustion of fuels (b) Air compression (c) Ceramic storage heaters (d) Combinations of (b) and (c) (e) Electric arcs	Heat transfer to moderately high Mach numbers Study of cooling methods Behavior and development of materials and structures including aerothermoelastic problems Aerodynamic problems to Mach numbers approaching perhaps 15 with continued development	Correct enthalpy and Reynolds numbers for Mach numbers of around 7 Mach numbers in the range from 12 to [illegible] attainable with incorrect enthalpies Continuous flow for practical purposes
Cold' hypersonic tunnels	Aerodynamics of perfect gas hypersonic flows Model configuration studies Exploratory aerodynamic research to high Mach numbers	Mach numbers to about 9 or 10 in air, incorrect enthalpies Mach numbers to about 20 in helium.
[illegible] tunnels (U of Calif.)	ICBM drag and stability at maximum	Low velocity and low density only to about Mach 3

Source: AGARD Report 132 by E. O. Pearson, Jr., and Aviation Week.

feets, vibration, accelerative loadings, intense light and complete darkness, pressure, temperature and other environmental problems.

Centrifuge Facilities

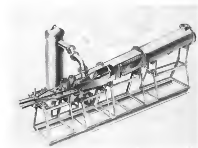
A number of large centrifuges are available for studying human reaction and structural and systems behavior under various accelerations. Probably the most advanced human centrifuge is the Navy one at Johnsville, Pa., which is operated in conjunction with a large computer in order to simulate the exact flight programs proposed for future aircraft. Scott Crossfield has ridden this centrifuge, for instance, to acquaint himself with the actual G forces he will face on flights in the X-15.

Rapidly alternating vertical accelerations that may be experienced by pilots during re-entry from a satellite orbit into turbulent air also are being simulated, using a seat that travels rapidly along a vertical rail or cylinder. Very low pressure chambers for testing pilot equipment, auxiliary equipment, and physiological reactions also are numerous.

New facilities being mentioned by human factors and structural engineers include high speed particle accelerators, adapted to simulate radiation effects, and rooms in which the intense contrast between light and shadow in space can be simulated. Some of these radiation problems are probably in the same category with weightlessness, which up to now cannot be simulated properly on earth. For much testing with regard to space flight a laboratory in space itself is the only answer.

The many hypersonic flow and structural problems that must be answered before man fully utilizes the propulsion power now available to him will require a wide variety of test facilities.

An excellent run down of present



CAL tailored interface tunnel's reflected shock wave technique gives longer test times

hypersonic test techniques and equipment is available in the NATO Advisory Group for Aeronautical Research and Development's (AGARD) Report 132 by E O Pearson, Jr, of NACA. This report outlines the capabilities and limitations of each technique and the type of problems for which each is suitable (see table).

Probably the most important point concerning high speed testing above Mach 4 or 5 is that no single technique or device is able to simulate free flight conditions completely. Various parts of the problem must be studied separately, and considerable skill must be used to correlate this data into a complete correct picture.

Ordinary wind tunnels cannot simulate free flight conditions because the stagnation temperature of the air at about Mach 5 is seriously close to the melting point of existing tunnel construction materials. The large pressure drop that occurs in the tunnels also makes liquefaction of tunnel air a problem. Wind tunnels then are able to hold the correct Mach number and somewhat applicable Reynold's number and are useful for stability and control work, drag studies and most other problems except those that require duplication of the flight temperatures above about Mach 4.

Flight Temperature Studies

One of the primary tools being used for heat transfer studies and other studies that require correct flight temperatures and enthalpy is the shock tube. The shock tube itself is adequate to Mach numbers of about 3 but it may be used with a nozzle to reach much higher figures. The primary limitations of the shock tube tunnel are very short testing times and an inability to simulate Mach number, enthalpy and Reynold's number at the same time. Either Mach number and enthalpy or Reynold's number and enthalpy can be maintained.

Shock tubes have been used by many investigators to study high temperature gas effects and flow characteristics about, and heat transfer to, various simple small scale shapes. Other experimenters have worked with "cold" shock tubes that employ helium as a test fluid. In this work flight enthalpy is not produced but flow characteristics about a model are simulated up to Mach numbers as high as 20. Problems of operating high temperature equipment are avoided in this way and one portion of the flight problem can be easily studied.

A large number of "hot" shock tunnel modifications have been tried which are designed primarily to increase the available test times. Shock tunnels generally create a gas flow of precisely known characteristics and their accuracy in reproducing data is very good.

One of the most recent refinements in shock tunnel design, which increases the available testing time of conventional equipment up to 25 times the old figure, has been placed in use by Cornell Aeronautical Laboratory. This device, called the tailored-interface shock tunnel, also reduces the attenuation problem of large length-to-diameter ratio tunnels.

A primary problem of designing shock tunnels is that long shock tubes are

needed ahead of the nozzle so that a long pocket of high temperature gas can build up behind the shock and a correspondingly long testing time can be obtained. But the longer the tube the greater the attenuation of the shock wave and the less accurately the properties of the gas in the test section can be estimated.

It is difficult to answer this problem by using a very large diameter and short length for the shock tube because of structural problems.

The Cornell tailored-interface tunnel uses a reflected shock wave technique to provide relatively long test periods with a short tube and little attenuation.

The tube on this tunnel is 28 ft long, and some tubes with shorter testing times are 200 or 300 ft long.

Testing Time

Normally the testing time of a shock tunnel is limited to the time interval between the arrival of the incident shock at the nozzle and the arrival of the wave generated by the reflection of the incident shock from the nozzle and interface between the high pressure driving gas and the low pressure driven gas. If the driver and driven gases are at the same pressure and velocity the reflected shock can pass through the interface without creating any additional waves and the test time is prolonged. Proper tailoring at each Mach number is achieved by mixing helium and hydrogen at specific temperatures. By heating the hydrogen driver gas to 1000K°, full temperature simulation up to Mach numbers of 20 or 22 is reported possible.

Increases in test up to 25 times normal are possible if a supersonic convergent-divergent nozzle is placed at the diaphragm station that separates the high pressure driving gas from the low pressure driven gas. If this nozzle is not used, test time increase amounts to about 8 times normal. The penalty for the longer times is that a different nozzle must be used for each Mach number desired, and more power is required.

Temperature Tunnels

One of the most important problem areas is in providing high temperature tunnels large enough to take reasonably sized structural models and test them for relatively long periods (minutes). NACA has completed a 9 by 6 ft thermal structures tunnel at Langley Field which has a stagnation temperature limitation of about 660F. Air for this tunnel is heated in a pebble heater. Smaller tunnels using hot ceramic heaters have a general limit of about 2,500K. Electric arcs or plasma jets can reach stagnation temperatures corresponding to high Mach numbers but the plasma flow does not simulate the expected air flow in any way.

One device called a wave superheater has been financed by the Air Force Office of Scientific Research and built by the Cornell Lab. It will provide a test period of minutes and have a one foot square test section. It will have the same general flow characteristics and limitations as a shock tunnel except for the longer testing time.

Equipment with these capabilities are extremely important for structural work during the next few years.

Superheater Utilization

The wave superheater is essentially a large number of shock tubes attached to the outside of a large rotating drum. During each revolution of this drum the shock tube is charged with low pressure gas, which then is driven into a nozzle and directed into the test section. During every cycle each tube also is flushed with a cleaning and cooling gas.

A small superheater has been in use for some time at Cornell to test the operating principles. The larger machine will allow virtually unlimited testing times for structural specimens in flow that accurately simulates hypersonic heating rates, flow patterns and temperatures. It will rotate at about 2,600 rpm and the temperature variation around the rotor will be about 30 to 40 deg. The rotor will be preheated to 650F before the tunnel is started.

The limiting factor in this tunnel's operation is the amount of helium gas it will use. In 7,200 seconds of operation it will consume about 2.5 million cu ft. Availability of this gas is critical and consumption is closely regulated. Also storage problems can become of major importance when testing times are long.

Test Section

The nozzle of the test section fed by the wave superheater's rotating drum can be cooled and used for adequate lengths of time, but they will erode and have to be replaced often.

Rocket models will undoubtedly be used for many years to come to provide much valuable information under correct test conditions. But they still have scale problems, are relatively costly, provide somewhat limited data from each shot and preclude close observation of flow phenomena.

Ballistic ranges have been improved greatly over the last few years and new light gas propulsion schemes have replaced older gas and explosive-powered guns. They have been useful at relatively low hypersonic speeds for determining skin friction drag, total drag, boundary layer conditions and dynamic qualities of basic shapes. ■

ATLAS launching complex will be utilized for space vehicles using the ICBM booster, such as the Pied Piper satellite.

Canaveral Supports Space Exploration

Only a year after the first test firing of the first U. S. intercontinental ballistic missile, the Air Force Missile Test Center is well on its way into its role of supporting the exploration of outer space.

For six months this $400 million complex of range and test facilities has been the take-off point for U. S. satellites. Within the next few months the center will serve as the launch site for the first tentative probing into lunar space.

Center Has Dual Role

Not far behind will come the test vehicles for reconnaissance satellites, bio-satellites and man's attempts to reach out to the realms of the nearer planets.

All this has been imposed on top of its rapidly expanding burden of supporting tests of medium and long range missiles for all three services.

This double role has brought about a 75% expansion in personnel and operating costs in two years time. With its location relatively near the equator and in a position to take advantage of the earth's rotation in launching space vehicles eastward, its role of "space port" will continue to expand as rapidly as its missile testing function.

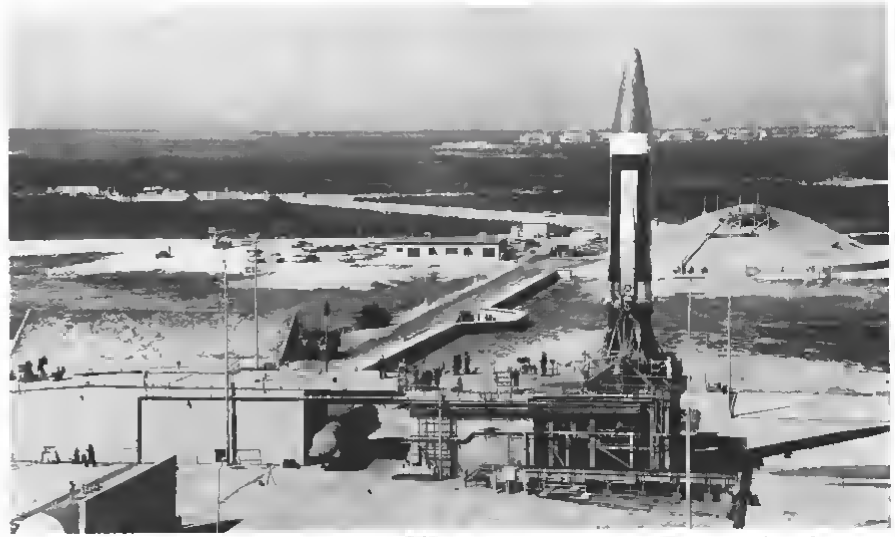
The Missile Test Center, under the command of USAF Maj. Gen. Donald N. Yates, is the largest and most intricately instrumented range complex in the west and perhaps in the world. It is a center of the Air Research and Development Command.

It consists of 225 separate parcels of real estate scattered along the central part of Florida's eastern shoreline and strung more than 5,000 mi. southeastward across the Atlantic Ocean to Ascension Island, below the bulge of the West African coast.

Main parts of the center are:

- **Patrick Air Force Base**, an 1,822 acre installation on the site of the old Banana River Naval Air Station. This houses the center's headquarters and its administrative, engineering, logistics and aircraft operations.
- **Cape Canaveral Auxiliary AFB**, 18 mi. north of Patrick. This 14,513 acre triangle of sand and palmetto is Range Station No. 1 of the Florida Missile Test Range, and the launch site for all the center's missile firings. In addition to its landing-strips, concrete launching pads, service towers and blockhouses, it is the site for central control of the range, radio transmitters and receivers, telemetry receivers, missile assembly

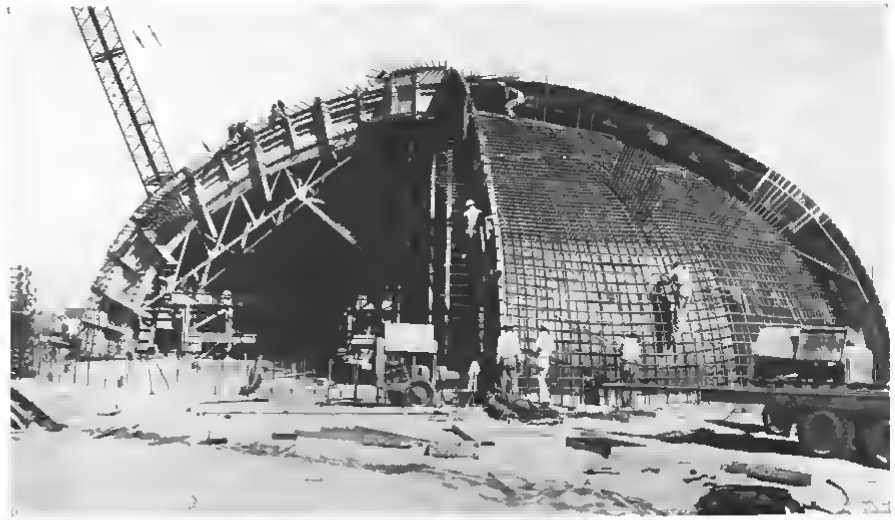
AZUSA impact predictor uses phase comparison technique to track ballistic missiles. Antennas are arranged in form of cross.



CLOSE-UP of Atlas pad shows launch stand, blockhouse, missile assembly area (hangar type) buildings in far background

buildings, guidance laboratories, a 75-ton per day Air Products, Inc., liquid oxygen plant, optical and photographic tracking equipment, and support buildings such as the power station. At its south end a deep-water port is being completed to handle ocean going vessels involved in Navy's Polaris fleet ballistic missile program.

● **The range itself,** consisting of 11 major downrange tracking stations, one on the Florida coast and the rest on island of the Bahamas and West Indies and out to Ascension, a dozen small telemetry and optical tracking stations scattered along the mainland and manned only during tests, and 11 ocean range vessels that bridge the 3,450 mi. gap between St. Lucia Island (Station 10) and Ascension (Station 12). The eleventh station, on the island of



TITAN blockhouses designed by Blaw-Knox Co. are under construction at Cape by Diversified Builders, Inc., of Montebello, Calif.

Fernando de Noronha 300 mi off the Brazilian coast is being completed now. In addition, a Minitrack station has been installed on the island of Antigua, north of St Lucia, to monitor Vanguard and Explorer satellites

$10 Million Payroll

Although it has been only eight years since the first missile was fired from Cape Canaveral and only five years since the center became operational, payroll for military and civilian government employes (plus a few small expenses) totalled $9,670,000 in a recent month—up more than $3 million from the same month in 1957. Annual operating costs run at about $100 million

Population of the center now stands just below 17,000. This breaks down to 2,800 military, 2,500 civil service, 4,000 missile contractor personnel, and 7,300 range contractor personnel. Since the center's growth began there also have been several hundred construction contractor personnel in the area

Pan American World Airways, Inc., is the principal range contractor, taking care of the housekeeping duties and running a downrange airline out of Patrick to service the tracking stations

Radio Corp. of America, as sub-contractor to Pan American, operates and maintains most of the instrumentation at Canaveral and along the range, and performs engineering and data reduction work at Patrick

Range and contractor personnel breakdown by locations is

- **Patrick AFB**: Pan American, 1,000, RCA, 1,600; missile contractors, 480
- **Cape Canaveral**: Pan American, 2,100, RCA, 590; missile contractors, 3,500
- **Downrange**: Pan American, 1,170, RCA, 580; missile contractors, about 70

The range has grown step by step to meet the needs of missile contractors. Sites as far downrange as Station 7 on Grand Turk Island have been operating for 4½ years to support firings of the tactical Martin Matador and Northrop Snark intercontinental cruise missile.

Station 8 in the Dominican Republic was not activated until late in 1956, as the increasing range required in Snark tests made it necessary.

By the time that Army Jupiter and USAF Douglas Thor intermediate range missiles came into the test firing stage last spring, stations were ready for them as far downrange as early tests called for the missile to go.

The lonely downrange sites are manned by an average of 80 to 180 civilian technical people. Size, location and composition of the station depends on the type and quantity of the tracking instrumentation called for.

A typical station includes a pair of

radars to track and record the missile's position, a telemetry receiving station to pick up the bulk of intelligence from the missile in flight, communications and a command transmitter to control or destruct the missile, a timing generator, and a weather observation station. Stations near impact areas also maintain photographic equipment.

Each station has one Air Force officer in command, plus a civilian commander. The rest of its complement is contractor employes. Each station must be self-sufficient, maintaining its own food, medical, fire, security and recreation services and motor pool, and often relying on rain catch basins for its water. Nine have small airfields.

The eleven electronic picket ships, operating out of South American and African ports, range from 350 to 3,500 tons and carry special telemetry antennas and receiving and recording equipment.

The center's 42 aircraft include a specially-equipped B-17 that flies the range before a shot, sweeping it with radar and relaying the radar return to the Central Control Building on the Cape, and a C-131 interference monitoring aircraft that watches the dozens of radio frequencies used in tests.

Cape Canaveral's landing strip will accommodate C-124 Globemasters and the Douglas C-133. Missiles are assembled and checked out in the industrial area composed of 17 large, hangar like buildings.

Contractors now active at the Cape include Martin Co. (Titan and Matador), Douglas Aircraft Corp. (Thor), Lockheed Aircraft Corp. (Polaris), Boeing Airplane Co. (Bomarc), Convair Division of General Dynamics Corp. (Atlas), Northrop Aircraft, Inc. (Snark), Fairchild Engine and Aircraft Corp. (Bull Goose), North American Aircraft, Inc. which has just completed its initial Navaho program, Chrysler Corp. (Redstone and Jupiter) and a number of component contractors such as General Electric, Avco and Rocketdyne.

Three main launching areas mark the Cape's coastline. Smaller missiles including Matadors used in operational training firings are launched from a battery of simple pads at the Cape's tip. To the south are Redstone, Jupiter, Thor, Vanguard and Navaho areas and along the northern side are four Atlas pads, four Titan complexes now under construction, and an underground installation for the Polaris ship motion simulator launcher.

So far, space vehicles have not called for appreciable modification of launching and servicing equipment. Vanguard has its own pad and tower, and Explorer satellites, launched with the Jupiter C test vehicle, have used existing Army facilities.

Servicing of the Thor-Vanguard

combination known as Thor-Able was accomplished from a Thor tower. Further modification of IRBMs and ICBMs, however, might call for special equipment or changes in existing service towers, ground handling equipment, trailers, etc.

Air Force's lunar probes, for instance, will consist of a Thor topped by an Aerojet second-stage Vanguard engine, topped by a third stage and nose cone.

Since Thor test vehicles carrying components of Pied Piper reconnaissance satellite and later the planetary probe vehicles, will be fired from Canaveral, a great deal of thought has to be given not only to the added workload but to the peculiar handling and tracking requirements of these vehicles.

Nerve center for control of firings from the Cape is the Central Control Building. Pan American's superintendent of range operations heads a team consisting of RCA communication, instrumentation and interference monitoring managers, PAA's range clearance manager, an Air Force weather forecaster and range safety officer, the aircraft coordinator, and the missile project officer.

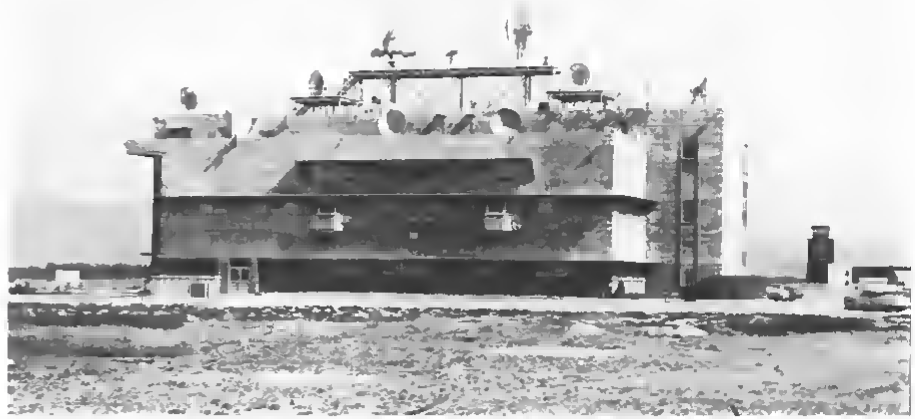
Range instrumentation includes high speed cameras and theodolites, two Doppler velocity and position systems, the 500 in. focal length ROTI camera for photographing missiles in flight up to 200 mi., other telemetry and radar systems, and the Azusa impact predictor system which employs electronic phase comparison techniques to determine position of ballistic missiles out to altitudes of several hundred miles. Azusa measures direction cosines to an accuracy of two parts per million and can detect changes in position of 15 to 30 ft. up to a range of 500 miles.

Four telemetry antennas allow the range to cover the 5,000 mi. trajectory of a ballistic missile. The system in use now collects as many as 250,000 data points on as many as 175 separate functions per flight.

Radar tracking data from down range is fed back to the Cape via submarine cable, and information necessary for control during flight goes directly into an IBM 704 computer.

At the end of a flight, data is reduced automatically in other computers and processing facilities and translated into a Flight Test Report for the service or contractor whose missile has been fired.

In addition to its testing, test support and evaluation missions, and its new space support mission, AFMTC also has responsibility for organizing and training military crews in checkout, maintenance and firing of production line missiles. Matador, Snark and Bomarc units already have been trained there. ■



FLIGHT test control building, Naval Air Missile Test Center, Pt. Mugu, Calif., is used for combat information center type operations.

Vital Role Set for New Missile Range

By Russell Hawkes

Launch sites and range facilities in the loose-knit confederacy of the Pacific Missile Range are slated for important missions in military technology and the advance into space.

Notable ones will be:

- Launching of polar orbit satellites, including military reconnaissance devices
- Training of first USAF ballistic missile squadrons, including actual firings
- Training and confidence shots of Navy's entire missile arsenal by operational fleet units
- Research and development flights of Navy cruise missiles and advanced small and middle sized rockets

Pacific Missile Range is the Navy-led tri-service administrative agency charged with coordinating all West Coast missile activities which cannot be confined within the boundaries of a single military reservation In other respects Cooke AFB and Navy missile ships using the range retain their autonomy

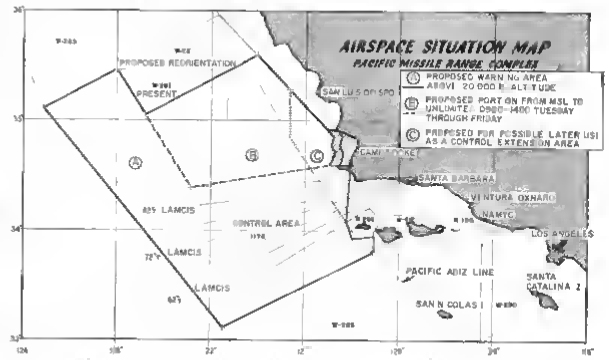
Naval Air Missile Test Center at Pt Mugu, which is the nucleus of PMR, and the newly commissioned Naval Missile Facility-Pt Arguello are the only full-time PMR bases, being directly under the command of the Pacific Missile Range commander, Rear Adm. Jack P Monroe

Pt Arguello is seen by Navy as a base for all services and civilian space agencies, but the degree of usefulness to other services is not yet clear Army lacks a suitable West Coast launch site and small rocket range Navy has asked $3.6 million to support Army firings in next year's budget USAF has Cooke AFB to use as site for operational training and research firings of ballistic missiles satellite reconnaissance vehicles and research rockets, but lacks a good West Coast range for small air-to-air and air-to-ground missiles and instrumentation for the bigger shoots

Neither Army nor Air Force has current plans to use Arguello. Navy is seeking space research projects to commence firing at Arguello sometime after spring of 1959 Base should be in full operation by the end of 1960

Proximity of PMR bases to Southern California aviation and electronics industries which supply many of the nation's missiles may lead Army and Air Force to do some testing of small and middle sized missiles there rather than at eastern or inland bases

Bases in the Pacific Missile Range complex are favored by geography for some space research, peacetime strategic



AIRSPACE situation map of Pacific Missile Range complex showing proposed control areas.

AIRVIEW of Cooke AFB showing buildings being rehabilitated at cost of $100,000,000

missile and reconnaissance satellite shots. Mugu and Cooke-Arguello are located at opposite ends of a 100 mi stretch of coast northwest of Los Angeles and on opposite sides of Santa Barbara. The shoreline runs straight west from Santa Barbara to Pt. Arguello where it turns straight north.

The naval missile facility is located there on the south 20,000 acres of Army's old Camp Cooke. Cooke AFB is immediately adjacent on the north 64,000 acres of the old Army reservation. From this position on a right-angular point of land it is possible to fire long range rockets over the Pacific Ocean on any course from south to west by northwest without endangering population centers.

Launch to the north or south is obviously necessary to establish a satellite in a polar orbit. No other existing U.S. base can use these directions and only a polar orbit offers the chance of scanning the entire surface of the earth within 12 hr. Any military reconnaissance satellite such as that expected to grow out of the WS-117L program, is likely to require a polar orbit to cover the northernmost regions of the Soviet Union.

Use of satellites for meteorological research or routine weather data collection is likely to involve Pacific Missile Range because of the advantages of a polar or near polar orbit for producing a synoptic picture of world weather.

From the standpoint of performance

THEODOLITE station on San Nicolas Island used for tracking missiles.

required of the propulsion system the polar orbit is unattractive because no 1,000 mph boost is supplied by rotation of the earth as in the case of west-to-east equatorial orbit. Because of this, Pacific Missile Range is unlikely to be assigned lunar probe launchings or firings into more distant space.

These more advanced space research projects will fire as close to due east as possible with the given mission to get the advantage of the rotational boost. This makes the Atlantic missile range at Cape Canaveral the logical choice for a launching site.

When 10,000 mi. missiles and boost-glide bombers similar to Dynasoar reach the flight testing stage, a westward launch may be found desirable to minimize actual range, while simulating polar or eastward flights of much greater range. Impact areas in the Pacific Ocean are available to the west of Cooke AFB and Pt. Arguello which could not be reached from White Sands or Canaveral without overflying major cities.

To the East, PMR bases are separated from the desert only by sparsely settled mountains. This makes it possible to launch cruise missiles and smaller rockets inland.

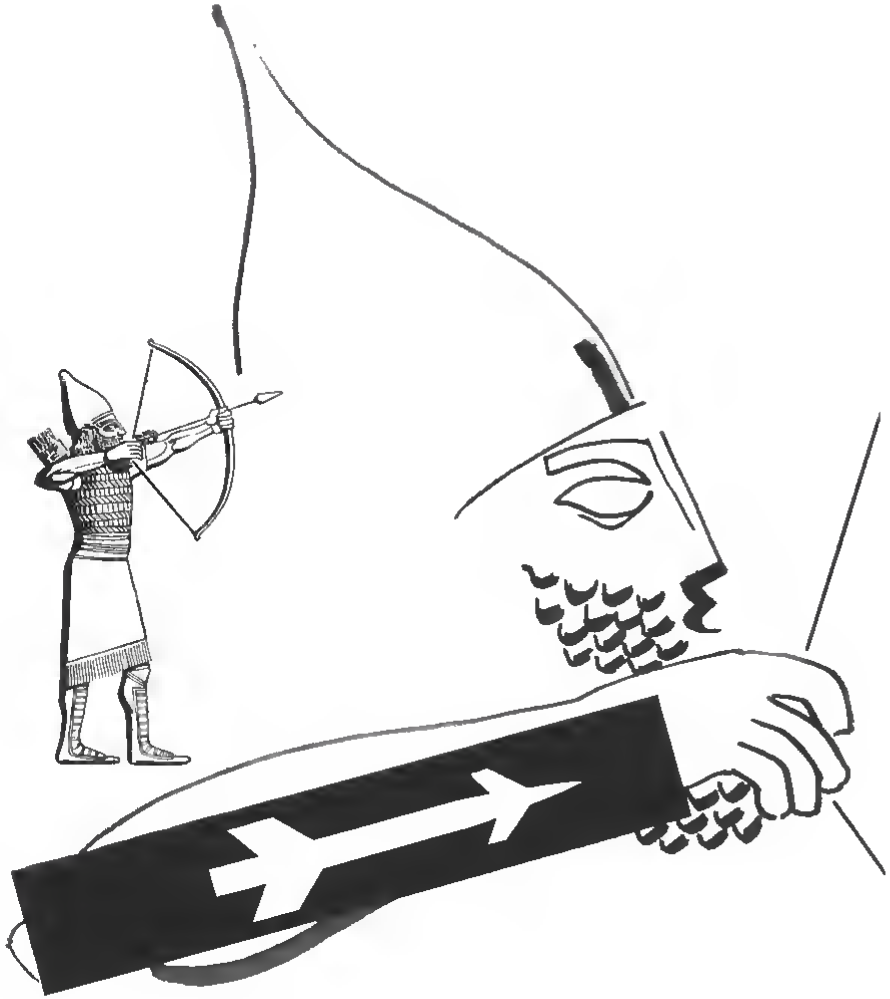
Pacific Missile Range was created when it became apparent that the two existing major ranges at Cape Canaveral and White Sands would be inadequate for planned firings because of saturated schedules and lack of long range corridors to the south and west. The Secretary of Defense's Committee on Adequacy of Range Facilities was appointed a year ago to find a solution, and recommended the creation of PMR.

Navy was chosen to manage it because the Naval Air Missile Test Center at Pt. Mugu offered a fully established nucleus around which PMR could be organized. Also Navy was only service without management responsibility for a major missile range. New range was formally conceived by a Defense Department directive on Dec. 7, 1957.

Twelve-year-old Mugu has an instrumented sea range 500 mi. long by 250 mi. wide with 18,000 acres of land, including a chain of offshore islands which are used for launch pads and instrumentation sites.

In the current fiscal budget, $21 million have been allocated for construction of PMR facilities. Arguello will receive $10 million of this and the remainder will be spent on instrumentation along the coast and at San Nicolas Island, the major offshore installation. Construction program will spend $150 million in the next four or five years. Work will begin at Arguello in July. Architectural and engineering contract is held by Aerojet-General. Navy has asked $34.1 million for PMR in the amendment to the Fiscal 1959 budget.

Another $100 million is being spent



THE MISSILE MEN

From the earliest Assyrian "artillery missile —with the flint-tipped warhead and hawk feathers for a guidance system— the fate of nations has been in the hands of the missile men

Today, our strength in military missilery may hold the key to survival

Martin based its long-range planning on that probability in 1946 with the development of one of this nation's first successfully operational guided missiles. The result is the *total missile* concept

Under this concept far more is involved in missile system contracting than the design and production of hardware

The testing, packaging delivery, maintenance, launching, operation, field training and contractor service requirements make up the *total* story of missile performance— in the air, and operated by the military personnel

The heavy demands of our country's greatly accelerated missile and space development programs now emphasize the importance of Martin's total capabilities as a major resource for the military and astroscientific branches of the government

Among those capabilities are three plant facilities which include the newest and most advanced missile development centers in the world.

Also part of these Martin capabilities is one of the great U S resources in manpower More than 3,000 specialist engineers, trained and teamed in the *total missile* concept

This is one of the few systematically organized companies of genuine Missile Men in the country.

MARTIN

BALTIMORE·DENVER·ORLANDO

at Cooke AFB and much of the work is nearing completion. Cooke is an operational base for Atlas ICBM squadrons of the First Strategic Missile Division of Strategic Air Command. Cooke will also train all of USAF's Thor IRBM crews, and many Atlas crews. First full scale Atlas for class room training was recently delivered.

First PMR Thor Launch

Cooke will launch its first Thor into the Pacific Missile Range this fall. British Royal Air Force Thor crews will begin to arrive for training in July. Construction on Thor pads and ground servicing equipment is over 80% complete. Primary missions of Cooke are operational and training rather than developmental but live training shots will probably carry telemetry to wring the last bit of value from each expensive firing.

Inland range of PMR has already begun operations. It runs from launch sites at Pt. Mugu or San Nicolas Island to the Army Dugway, Utah Proving Ground or the AEC test site at Tonopah, Nevada. Only missile now using the inland range is Chance Vought Regulus II, which began runs there late last month.

Regulus runs are being scheduled at the rate of one per week with Navy and Chance Vought administering alternate flights. Chance Vought has also been given operating contract for instrumentation of inland range. Mobile instrument vans and trucks are driven to pre-surveyed sites shortly before a run is scheduled. First run was a warhead firing mechanism test and the missile ran to impact.

Civilian operating contractors will have more limited scope in Pacific Missile Range than at Canaveral because Navy is convinced it can handle the management function more economically by itself. Operating contractors usually will be limited to handling such jobs as running transportation pools or operating single instrumentation ships and advanced base tracking sites.

Construction at NMI Pt. Arguello will include only technical and training facilities. Living quarters and recreation facilities for Arguello personnel will be at Cooke AFB or in nearby civilian communities. Roads in the Arguello-Cooke area are not well developed and the Navy facility will be largely dependent on the airfield at Cooke for logistic support.

Present 4,200 ft. runway is inadequate and Air Force is laying down a new 8,500 ft. strip to handle Douglas C-124 and C-133 ballistic missile transports. Construction at Cooke is administered by Army Corps of Engineers.

Since the primary missions at Cooke are wartime operational and training shots rather than research and development firings, the missiles will not or-

dinarily be tracked beyond burnout At this point the remainder of the trajectory is certain and the only remaining information of interest is the exact impact point Ships assigned or leased to the Pacific Missile Range will determine this by the Sofar technique which is also used at Canaveral

Explosive charge carried in missile nose makes loud noise which can be heard at great distances by highly sensitive Sonar In instrumentation ships Triangulation of the bearings on which the explosion is heard makes possible reasonably accurate location of impact

Pacific Missile Range policy is set at Defense Department level by a tri-service joint planning group Policy is interpreted and over-all direction is supplied by a tri-service committee headed by Adm Monroe There will be tri service specialist committees to provide technical policy interpretations

As commander of the national Pacific Missile Range, Monroe will also run the working staff USAF Maj Gen David Wade, commander of the First Missile Division, reports a high degree of cooperation between his own organization and the Navy range managers Wade is also the Air Force member of the Washington based joint planning group for the Pacific Missile Range, led by Rear Adm W E Gentner, Jr Army member is Maj Gen D E Beach

Inevitably, creation of the range has called for measures to safeguard air and surface traffic As range manager, Navy has proposed creation of a restricted area over Cooke AFB and NMF Pt Arguello and extending to the three mile limit Beyond this Pacific Missile Range will ask for a warning area where operations cause a hazard to air traffic

The Cooke Arguello restricted area was originally suggested as a prohibited area The change substitutes safety reasons for security reasons in closing the area to civil air traffic

Aircraft Owners and Pilots Association is opposing creation of the restricted area on the grounds that it will cut off North South travel in cloudy weather by private pilots without instrument capability Many of these follow the beach in marginal weather and AOPA feels it would be hazardous for them to try the mountain passes

An Transport Association is backing up AOPA because Los Angeles Regional Air Space Subcommittee is recommending adoption of the warning area requested by the Pacific Missile Range, which lies across Los Angeles' Multiple Corridor Identification System (LAMCIS) and extends upward from 20,000 ft This would force transpacific flights approaching Los Angeles to remain below that altitude and, in the case of jet transports, might prevent use of most economical altitude

LAMCIS approach channels are re-

quired by Air Defense Command to simplify identification of incoming aircraft. Only remaining transpacific approach to Los Angeles unrestricted in time or altitude is via Catalina. Navy said it is willing to work out a plan with airlines but ATA may refuse to fly under missile trajectories.

There is no plan to create an airspace reservation on the inland range between Pt. Mugu and Army's Dugway, Utah, proving ground along which cruise missiles will be tested. Proposed minimum altitude for missiles to overfly uncontrolled airspace is 20,000 ft. Ordinarily Regulus II or any other cruise missiles likely to be fired on the inland range would operate far above that altitude.

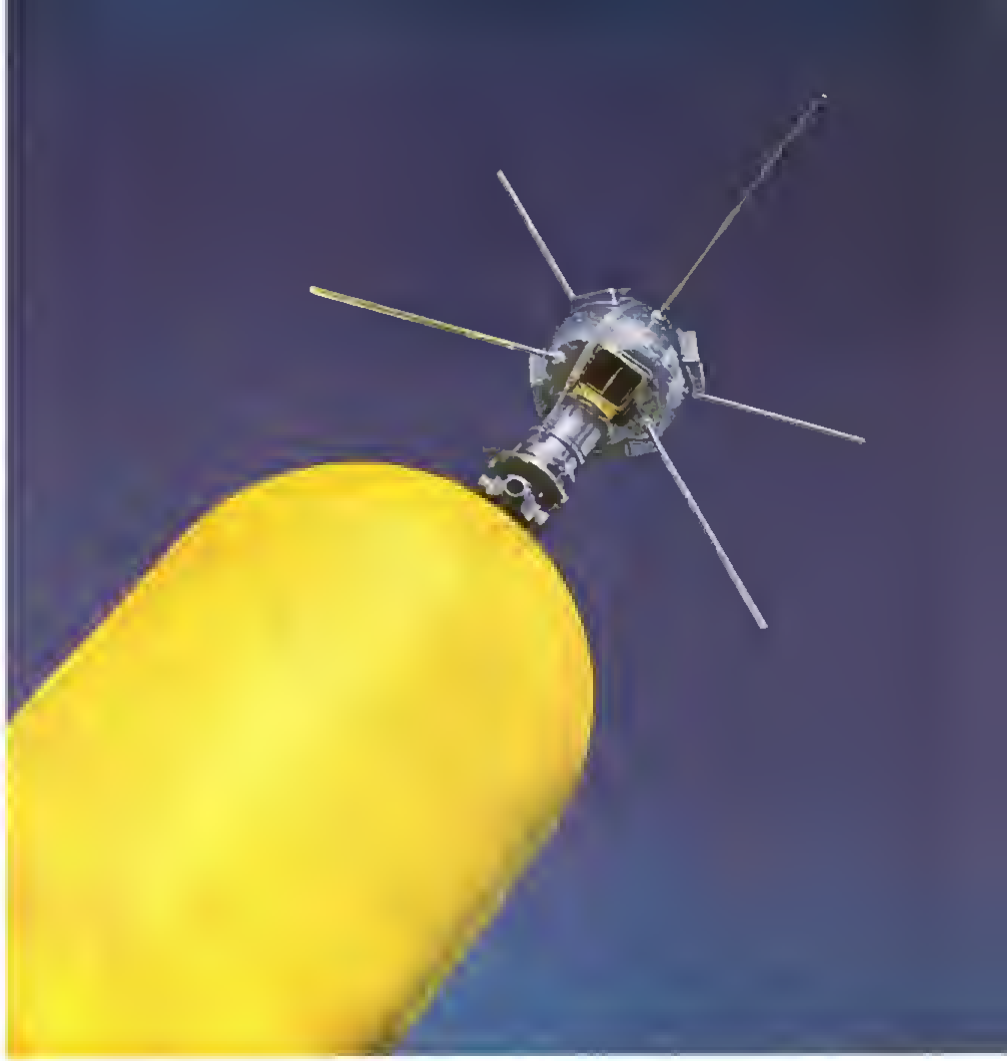
Destruct button can be pushed by a range officer on the ground or by the pilot of the chase plane. Navy estimates hazardous fallout caused by destruction of a missile to be on the order of one chance in a million. The sea range extends as far to the south and west as necessary without any significant limitation on length. PMR says ballistic missiles fired from Cooke or Arguello may cross air routes between Hawaii and the mainland but at such an altitude as to cause no danger to traffic. They will follow a track 600-800 mi. north of the Hawaiian Islands.

Surface traffic also is a problem. Ships outside the three mile limit are not subject to positive control by Navy. However, weekly local notices to mariners, maritime equivalent of NOTAMS, will be published to warn shipping of planned firings and impact areas. Routine range surveillance will keep range officers informed of the presence of traffic. Ships discovered entering impact areas will be radioed safe headings to steer on regular shipping communication frequencies.

Adm. Monroe estimates that in five years, training will constitute 25% of the total effort in the Pacific Missile Range complex but that the proportion of live training firings to other launches will be much less than this because of the increasing use of simulators.

Monroe pointed out that the live firing actually teaches no more than that the missile works. The big need will be for simulators capable of representing a complete weapons system. This would include a fighter director position in an operational trainer for air-to-air rockets.

Gen. Wade, at Cooke, agrees with Monroe about the value of simulators but reports that USAF is not expecting ballistic missile training simulators in the near future. He suggests that what is needed is a simulator at the operational launch site with the same blockhouse and guidance facilities used for simulated and real shots. Chief problem in simulator design is that of inducing a combat psychological situation ■



VANGUARD test satellite rests atop Grand Central Rocket Co. third stage engine at Cape Canaveral, Fla.

Avionics

Space Needs Spur Avionic Creativity

Returns on this nation's fast-growing investment in space exploration will depend in large part upon the ingenuity of avionics designers and manufacturers. It is therefore fortunate that the U.S. lead over the USSR in the avionics field is at least as great as their lead in rocket propulsion.

While hot arguments rage over man's value and role in space exploration, there can be no question of the value and role for avionics. They are limited only by the ability to slash size, weight and power consumption while improving reliability by several orders of magnitude.

With no cornfields in space for emergency landings, the price of failure in navigation equipment could be an endless journey to infinity for some luckless future space vehicle passenger.

The ability to sense, measure, and report back to earth on new or familiar phenomena that lie outside the earth's atmosphere depends almost entirely upon avionics.

Although the space traveler may be flying contact under VFR conditions, the seat of his pants will tell him nothing, and he will be completely dependent upon avionic flight instruments. Without such instruments his life may be in jeopardy without any obvious signs of danger.

Some of the space technology problems that challenge the avionics designer and manufacturer look deceptively familiar, such as reducing size, weight, improving reliability. But the several orders of magnitude improvement required suggest that past approaches will fall far short of space technology needs. Size, weight, power consumption must be slashed by a factor of 100. Reliability must be increased by at least a factor of 1,000. This will require fresh approaches and new concepts, as discussed in greater detail on p. 243 in the article on construction techniques.

Managing Stored Energy

The avionics designer, often criticized for having developed too many different solutions to the aerial navigation and missile guidance problem, will face the most challenging problem of his career in trying to come up with one space guidance system that can meet required size, weight, power and reliability limitations.

Because an airplane consumes fuel continuously throughout its flight, and normally carries sufficient reserve, the aircraft navigation system designer has not had to concern himself with minuscule errors in system accuracy or about such things as vehicle energy conservation.

Until the advent of nuclear or other new propulsion, space vehicle navigation accuracy will be largely determined by precision of initial guidance because the vehicle will have little available energy on board for corrective maneuvers. Under these conditions the timing, magnitude (or duration) of any mid-course corrective maneuver can irrevocably determine the success or failure to make planet-fall. Thus stored energy management becomes a vitally important new function for any space vehicle guidance system.

Communications system designers, long accustomed to using brute force techniques and working with hundreds or thousands of watts of power to cover distances of several thousand miles, now must scale down to fractions of a watt, yet provide dependable communications over distances of millions of miles.

New Concepts Needed

The challenge of space technology already has uncapped creative scientific thinking and removed obstacles to concepts that would have received a cold military shoulder a brief 12 months ago.

Wright Air Development Center's Weapons Guidance Laboratory has received three unsolicited proposals for radically different types of "all-electronic" gyros which use no moving parts.

One of them holds some promise of providing "fantastic accuracies," according to a WADC spokesman.

Significantly, none of the three companies proposing the novel devices is currently in the gyro business. WADC already has funded one of the proposals and expects to award contracts for the other two.

Military services are receiving a variety of space technology proposals, many of them unsolicited, some of them from companies without experience in aerial navigation systems field. Military service scientists generally concede that new concept type proposals which might have been thrown out a year ago are getting their closest analysis today.

Principal difficulty is in sorting out the "science fiction" type proposals from concepts that are sufficiently sound to warrant financial support.

Avionic designers need not await the advent of interplanetary travel to find challenging space technology problems. Military services are sponsoring, or looking for techniques suitable for use with a variety of sophisticated satellite vehicles.

- **Communications relay**—Use of satellites for passive relay stations to reflect line-of-sight radio frequencies half way around the earth is the first step. Next will come satellites equipped with receiver transmitter and tape recorder. Message received from earth will be taped, then played back subsequently upon command from the ground when satellite is over desired message destination.
- **Navigation**—Satellites equipped with small radio/radar transmitter whose orbit is accurately known, can provide navigation reference for ships at sea, aircraft or missile guidance.
- **Surveillance**—Electromagnetic reconnaissance for ECM purposes, infrared visual, cloud cover surveillance are the most immediate applications.

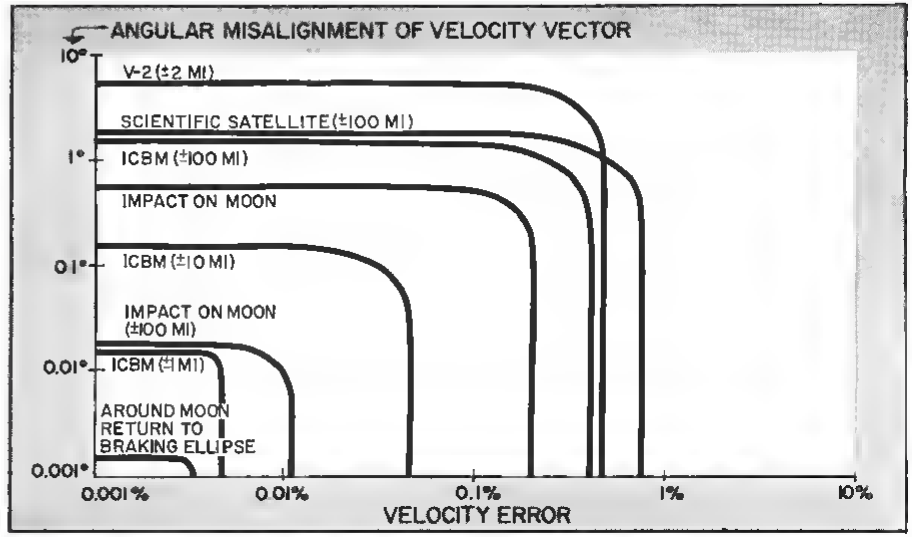
The possibility that one nation may seek to deny its space to another nation's satellite, means that ways must be found to alter the path of U.S. satellites once they are in orbit, to make enemy interception more difficult. Wright Air Development Center currently is seeking proposals for such a satellite control system.

Industry Impact

If the past is any criterion, avionic techniques developed to meet space technology problems will have widespread impact throughout the avionics and electronics field. Although neither the transistor nor the digital computer were developed specifically to meet an aviation industry requirement, the needs of the aviation industry greatly accelerated their development and application, which in turn have had widespread impact outside the aviation industry.

New molecular circuitry fabrication techniques, which show promise of slashing size and weight of avionic equipment and giving the vastly improved reliability required for space technology, will be quickly applied also to missiles and aircraft. These novel techniques are also certain to spill over into the industrial and consumer electronics fields.

Many of the problems of space technology will require totally new approaches on the part of the avionics engineer but, in the same manner as the other areas of the avionic art the demands made on his engineering abilities, creativity and skill will continue to increase for all of the foreseeable future. ■



COMPARISON of maximum allowable errors in velocity and injection angle for ballistic missiles and lunar probe vehicles.

Space Navigation Challenges Designers

By Philip J. Klass

Unless early space probes reveal existence of new phenomena which can be used for guidance systems, space navigation will present one of the stiffest challenges to avionic designers' ingenuity.

Whereas aerial navigation primarily involves two moving coordinates of the airplane and a single airplane velocity vector relative to a fixed destination, interplanetary navigation involves three moving coordinates of the vehicle and its three velocity vectors, plus the three moving coordinates and velocity vectors of the destination, plus "time" which determines location of destination upon arrival.

Difficulty of this task has been compared to the problem of a jet fighter, running low on fuel, trying to make contact with an aerial tanker engaging in acrobatics.

Space navigation is further complicated because minimum energy flight paths must be used and only limited fuel is available during flight to make required changes in vehicle speed and direction—until the advent of nuclear or other new forms of propulsion.

Command Guidance

To make matters more difficult, many of the techniques developed for aerial navigation will have only limited suitability for space navigation.

Initial space probing missions will depend upon ground-based command guidance of the launching vehicle, with no guidance of the space vehicle itself, because of severe limitations on payload. In this type guidance, the space vehicle is merely an unguided projectile aimed by an "avionic gun barrel."

Command guidance system developed by General Electric Co. and Burroughs Corp. for Atlas intercontinental ballistic missile or Convair's Azusa system is typical of the type of guidance system that may be employed. (AW April 28, p. 74.)

Use of launch vehicle guidance only places severe limitation on the types of space probes that can be made.

For example, to send a lunar probe vehicle circling behind the moon and back to within 500 mi. of the earth, so it can telemeter back its findings, will require controlling cut-off velocity of launch vehicle to within one part in 500,000, according to Lt. Col. G. H. Drewry, of the Army Ballistic Missile Agency.

In addition, vehicle's injection angle must come within 0.001 degree of the desired orbit and the instant of launch must be timed to coincide within 10 sec. of predetermined value unless a trackable launching platform is employed, according to Drewry.

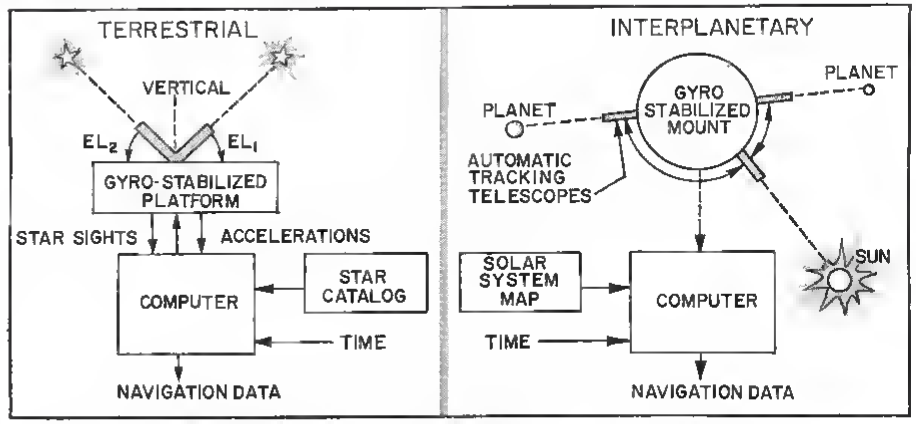
Elementary Guidance

Next logical step will be to add simple guidance capability to the space vehicle. This probably will be an extension of the radio command guidance employed for the launch vehicle.

However, such mid-course guidance can be no more accurate than the precision with which earth-based radar/radio tracking systems can determine space vehicle position and velocity vectors. Space vehicle will be required to carry a suitable radar transponder or radio transmitter. Several tracking techniques appear feasible for near-planet travel:

• Interferometer system, which compares phase of signal received from vehicle transmitter at four (or more) antennas arranged in the shape of a cross to permit determination of azimuth and elevation angles to the vehicle position. Navy Minitrack system used to track U.S. satellites is a representative system.

Use of several stations makes it possible to obtain vehicle velocity and position by triangulation. However, greatly



COMPARISON of automatic stellar-inertial navigators for terrestrial and interplanetary navigation use

creased base lengths between stations—of the order of several thousand miles—will be needed to achieve acceptable accuracy for short range interplanetary missions.

• **Pulse time system,** which determines range to vehicle from the time required for pulse transmitted from earth to reach the vehicle and time required for its reply pulse to be received. By using three or more stations separated by extremely long base lengths, triangulation will provide moderately accurate data on vehicle velocity and position for short range flights.

Shortcoming of any earth based navigation system is the relatively short base lengths that can be employed and the fact that the earth is rotating about its own polar axis. Advantage, relative to vehicle contained systems, is that there is no limit on size, weight or power consumption of ground based system.

By the time that interplanetary flight is feasible, it should be possible to establish navigation station satellites in orbits sufficiently great to provide base lengths of 50,000 mi. or more. However, this gain may be offset by problems of providing sufficient electrical power to enable satellite transmitters to reach out into space.

Self-Contained Guidance

It now appears that mid-course guidance of manned and unmanned interplanetary vehicles may employ self-contained systems. Although inertial systems may be used to determine changes in vehicle velocity and direction, it does not now appear likely that they will provide primary navigation means for mid-course guidance.

Schuler tuning principle, which is employed to prevent build-up of gyro drift errors during extended missions for aircraft and cruise-type missiles, relies upon earth's gravitational field for its operation. This field becomes too small to be useful for interplanetary missions.

Conceivably an inertial system could be Schuler-tuned by using sun's gravitational field. However, during a flight to Mars or Venus the sun's gravity is only 1/1,000 or less as strong as earth's gravitational field used by terrestrial inertial systems.

All-Electronic Gyros

But assuming that sufficiently sensitive instrumentation could be developed to measure direction of the sun's gravity, the period of Schuler tuning for a flight to Venus would be nearly one year, compared to 84 min. for earth-bound systems. This means that gyro drift errors would build up for nearly three months before starting to decrease, compared to an interval of only 21 min. in aircraft/missile inertial systems.

Inasmuch as total flight time to Venus would be of the order of only five months, flight would be over before Schuler tuning provided significant reduction of inertial system errors.

Although near-absence of gravity in space flight should greatly reduce drift of conventional gyros, a technological breakthrough is needed in gyro design to achieve the accuracies required for pure inertial mid-course guidance of space vehicles.

Such a breakthrough may be on the horizon. All-electronic gyros which operate on radically different principles and use no moving parts have recently been proposed to Wright Air Development Center by three companies. One of these, possibly using phenomenon of electron spin in paramagnetic materials, offers some hope of achieving "fantastic accuracies," according to a WADC spokesman.

All three approaches would eliminate need for ultra-precision machining and assembly procedures, and the problem of mass unbalance or shift which causes gyro drift. It is interesting to note that all three proposals came from companies that are not now gyro producers.

WADC also has received proposal for novel accelerometer which requires no moving parts.

Most promising mid-course navigation system for interplanetary missions now appears to be one that uses celestial techniques but with one major difference from present aircraft/missile system design. Absence of an earth gravity reference probably will require use of planet sights instead of stars.

In conventional aerial navigation the navigator measures the angle between an optical line to a star and his local vertical (direction of earth's gravity) to obtain a line of position. Intersection of two such lines obtained from two star sights provides position fix.

Unless it proves feasible to use the sun's gravitational field to establish a "solar system vertical" for equivalent reference, space navigators cannot use stars to fix positions. Reason is that the distance to the nearest stars is so vastly greater than the distances traveled in the solar system that angles of sighting would not change perceptibly during flight. For example, 100 million mile change in position of space vehicle would change sighting angle relative to another star by less than one second of arc.

This problem does not exist if celestial sights use the solar system planets

and the sun itself. Assuming the space vehicle is traveling in the ecliptic (the plane in which planets move about the sun), three celestial sights using two planets and the sun can determine vehicle position in the solar system.

Sighting Errors

Example of the effect of celestial sighting errors on the accuracy of a vehicle position fix for a flight to Venus is cited in a recent paper by E. V. Stearns of Lockheed's Missile Systems Division. For a space vehicle situated roughly 80 million mi. from the sun and 20 million mi. from each of two planets being sighted, an error of 30 sec. of arc in sextant and sighting would result in a 12,000 mi. error in position, in a direction perpendicular to a line to the the sun and about 3,000 mi. in directions perpendicular to lines connecting the vehicle with two planets.

This does not take account of possible errors in present figures on solar system dimensions or planet orbit data. Another source of error stems from fact that planets, unlike stars, are not a point source of light because of their relatively close distances. Trying to position an optical sight on a planet's center, particularly when its surface is partially obscured during phases (like the moon), may introduce additional error.

Velocity Vectors

Determination of vehicle position in space is only part of the navigation problem. It also is necessary to determine its velocity and direction of movement in order to determine the magnitude, or duration, and direction of thrust corrections that must be applied to place the vehicle on the required flight path to intercept the destination's gravitational field.

For guidance system designers, this requires a very basic change in thinking from present terrestrial concepts. For example, in aircraft and winged vehicles, amount of fuel consumed in making corrections in vehicle flight path is quite small compared to fuel consumed in making the flight.

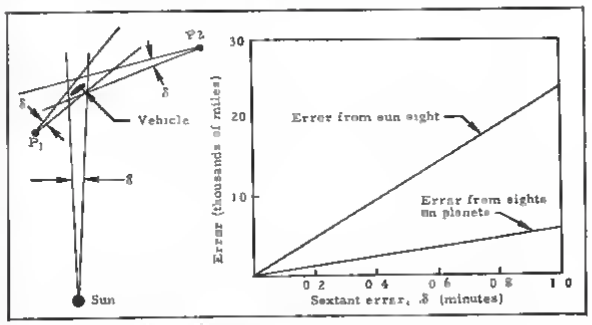
Once a space vehicle is outside the earth's gravitational field, the only fuel consumed is that required for guidance and terminal landing. With payload weight at great premium, the guidance system must not only determine the required changes in flight path, but the most economical time and means for executing them. Stored energy management will be a major problem.

If extremely accurate and frequent position fixes could be obtained, it would be relatively easy to determine magnitude and direction of vehicle velocity from changes in position. However, large errors or uncertainties in any single vehicle position determination require that long-term averaging be used to minimize errors in establishing velocity vectors.

For the earth to Venus mission cited above, with sighting errors of 30 sec. of arc, Stearns calculates that averaging vehicle position fix data over a 190 hr. interval could reduce probable error in computed velocity to about 3½ mi. per second and error in calculated heading to about 1½ milliradians.

An error of 1½ milliradians (roughly 0.1 deg.) seems extremely small by terrestial navigation standards. But Stearns points out that to correct for only a milliradian error in heading on a 150 million mi. journey when the vehicle is 5 million mi. away from its destination would require fuel equal to about 40% of the vehicle's gross weight, based on existing fuels.

"This represents an appreciable amount of fuel when one considers that fuel for landing and return voyage must also be carried aboard the vehicle," Stearns points out. If the celestial tracker error can be decreased by a factor of 10 to approximately three sec-



ERRORS in interplanetary navigation, based on celestial sights on two planets and sun, as function of sextant error.

in GROUND SUPPORT CONDIESEL

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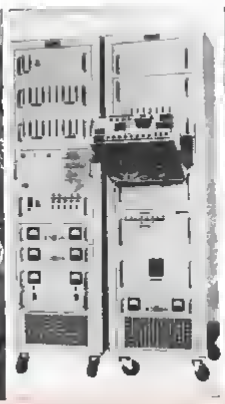

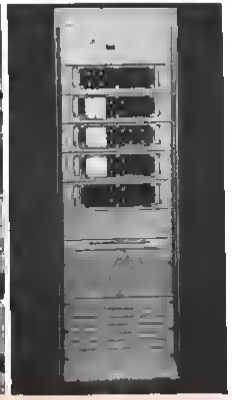

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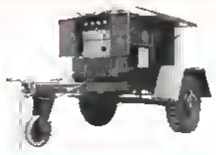

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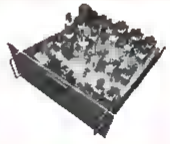
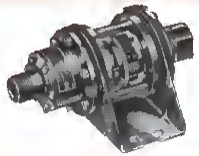


Computer Test Drawer

Motor Generator Set



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onds of arc, and if heading corrections were applied periodically during the mission, fuel consumed in maintaining the vehicle's course would be reduced to about 5% of gross weight

On this basis, Stearns suggests that interplanetary navigation will require a system made up of the following elements, with individual accuracies as indicated

- **Celestial tracker,** capable of establishing angles to two planets and the sun with errors of less than five sec of arc
- **Gyro-stabilized platform,** upon which tracker will be mounted, with gyro drift rates small enough to space-stabilize tracker during periods when planets can not be sighted or service is otherwise interrupted
- **Digital computer,** capable of computations to an accuracy of at least one part in 100,000
- **Solar system "map",** containing data on position of each planet at any instant in time, which can be stored in a form suitable for computer use
- **Time reference,** accurate to within one part in 100,000, which can operate for a year without re-calibration or loss of accuracy

To save weight, and minimize reliability problems, celestial sighting data might be telemetered back to earth, the required computation performed there in sophisticated digital computer, then telemetered back to the space vehicle

Other Ideas

The possibility of using Doppler or pulse radar in the vehicle to determine its velocity and/or distance from destination has been suggested, particularly since such a device may be needed during terminal portion of the mission to assure a soft landing But the problem of carrying equipment to generate sufficient electrical power to enable a radar with modest size antenna to send a signal out and back over a multi million mile path appears insurmountable until the advent of nuclear propulsion

Another interesting possibility for measuring vehicle velocity and checking its position, suggested by Dr John H. Hett of New York University, is the use of a device that measures intensity of the sun's infrared radiation

Using a star as a comparison standard, Dr Hett says it should be possible to determine vehicle distance from the sun to within several thousand miles

The problems of space navigation are sufficiently difficult that many observers are hoping that fundamentally new concepts may come out of newly discovered space phenomena New concepts also may come when avionic system designers and aerial navigation specialists acquire equivalent knowledge of celestial mechanics and when the astronomers turn their attention to space navigation ■

Wing bulkhead—Riveting a wing bulkhead for major assembly of Convair 880

Center wing spar assembly—Assembling the first center wing spar for the Convair 880

Tooling for 880—Primary assembly fixtures for fabricating wing spars being readied for stepped-up production of Convair 880

880 forward fuselage fixture—Checking the spacing of belt frames on metal mock-up—forward fuselage of Convair 880

Truss for 880—Assembling a truss-type bulkhead for wing of Convair 880

Skin and stringer panels—Large skin and stringer panels for center tie-box section of wing for Convair 880

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In order for Convair to maintain an effective, up-to-the-minute production timetable on the new Convair 880 Jet-Liner, every second of available time must be utilized efficiently. Obviously, a supplier that can meet and handle emergency material requirements, without causing the loss of valuable production time, is a must; that's why Convair, a division of General Dynamics Corporation, counts on U. S. Steel Supply in a tight situation.

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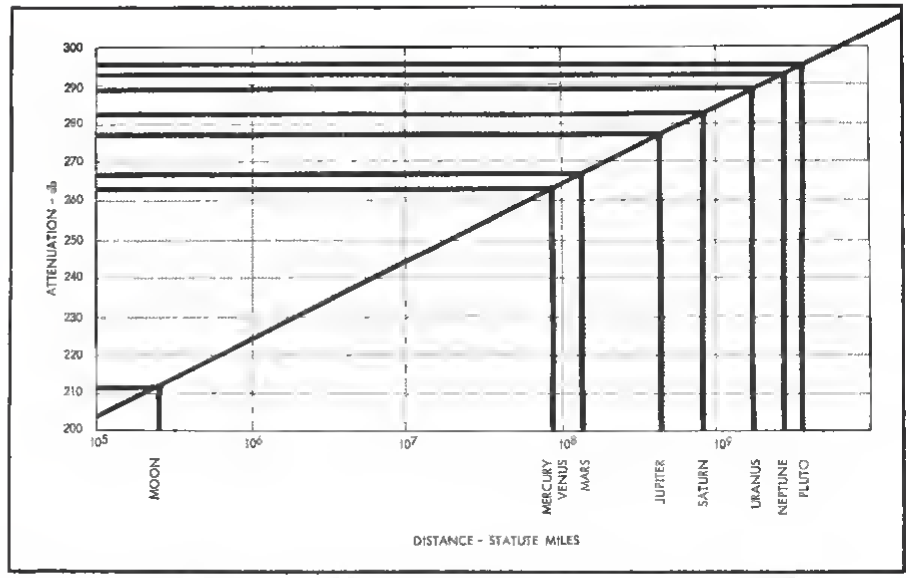


PATH ATTENUATION in db versus the average distance from the earth to the moon and to the other planets Attenuation is computed for a frequency of 2,250 mc and for path loss between isotropic antennas

Space Communications Techniques Ready

By James A. Fusca

Communications is one of the most highly developed aspects of space technology Problems of communicating with the moon and moon vehicles are now centered on instrumentation Mars and Venus are within range of state of the art techniques, the rest of the solar system is within reach of improvements already being explored

First steps in developing an understanding of space communications include:

• **Satellites** Better understanding of the electrical properties of the ionosphere is emerging as experience is gained in reception of data transmitted from both U S and Soviet satellites Navy is establishing a point to point communications system using earth's natural satellite, the moon, as a passive reflector to extend the range of line of sight frequencies for thousands of miles Man-made satellites are being studied for use as both passive reflectors and active relays

• **Space vehicles** Existing equipment can be used for communication with vehicles operating in cislunar space Primary problem is to obtain reasonably high gain from the vehicle's antenna without creating additional complex orientation and stabilization problems New and more sophisticated equipment will be required for communication with vehicles bound for Venus or Mars, but techniques for construction of such equipment are well understood at the present time For greater ranges communication probably will be by interplanetary relay

• **Interplanetary communications.** Communication systems to operate to Mars or Venus could be engineered today, while improvements such as much higher power transmitters, larger antennas and Masers for reception indicate that no overwhelming problems are likely to prevent development of equipment capable of operation throughout the solar system as rapidly as the vehicles that will require them

• **Beyond the solar system** At the present time there does not appear to be a solution to the problem of communicating beyond the limits of the solar system The closest star is more than four light years distant so, presuming that the communications equipment existed, time between transmission of a message and receipt of a reply would be about nine years There appears to be no way of circumventing the fundamental equivalence of space and time

Satellite Uses

First true space communications has been the telemetering of scientific data to ground stations from orbiting satellites Navy's use of the moon as a passive reflector for long range, point to point communications at line of sight frequencies indicates that similar use could be made of man made satellites

As future satellites become increasingly complex and as their missions are expanded demands placed on the communications systems will increase disproportionately A reconnaissance satellite, for example, might be required to store a large quantity of comparatively wide band data, such as the mapping information from an infrared or television scanner The satellite would then "dump" the stored data at high speed upon receipt of a properly coded interrogation signal

Some of the possible uses of satellites that are open to speculation include:

• **VHF area coverage** A satellite that received and retransmitted messages

broadcast in the very high frequency band would provide coverage of several thousand square miles with a simple, low power transmitter.

● **Countermeasures**: In the same manner that a satellite could be used to supplement battle area communications, it could also be used as an electronic countermeasures weapon. An interesting configuration would be a simple repeater consisting of a broad band traveling wave tube that would intercept and rebroadcast enemy messages or function as a jammer by rebroadcasting a jamming signal transmitted from the ground.

Communication throughout the solar system will be simplified by the fact that system's planets and moons all lie very close to the plane of the ecliptic. Therefore, rather than radiating energy omnidirectionally from a transmitter into space, energy can be concentrated in a beam that is omnidirectional in azimuth but with a width of about 30 deg in elevation.

By aligning the azimuth plane with the plane of the ecliptic, gain would be a factor of about 2.5 over a signal radiated omnidirectionally. The beam would include all of the system's planetary bodies and the probable routes between them.

Because a space vehicle can be expected to know its position in space, it would be able to make use of relatively high gain antenna which it could beam towards the ground station to be contacted. If it was another ship to be contacted, the message would probably be beamed to the ground station which would then rebroadcast it omnidirectionally, because of the relatively small transmitter power that would be available in a space craft.

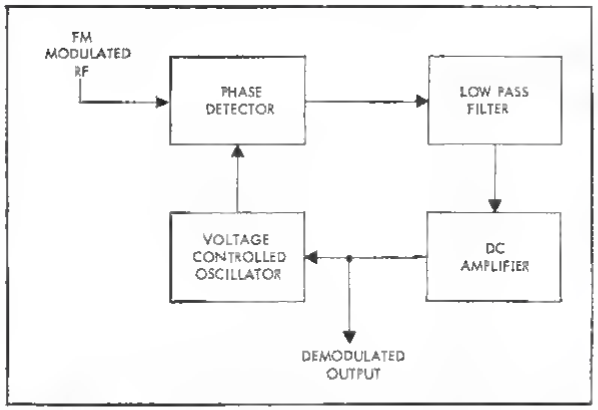
A ground station on the other hand, could be expected to use large, high gain antennas for planet to planet communications but not to contact space vehicles. Reason is that the time it would take to acquire a space craft with a pencil beam antenna when the position of the craft was not known could be prohibitively long and difficult. With sufficient power at the ground station and a sensitive receiver and moderately high gain antenna aboard the vehicle, ground station reception should not be a major problem.

A unique aspect of space communications will be the large frequency shifts resulting from the Doppler effect. P. A. Castruccio of Westinghouse Air Arm Division in a paper given before the American Rocket Society mentions that at X band a radial velocity of 10 mi/sec yields a Doppler shift of approximately 500 kc while at 100 mi/sec the shift is about 5 mc.

For this reason receivers will have relatively broad pre detection bandwidths or will use some method of signal tracking or Doppler gating to obtain the most favorable signal to noise ratio.

One detection technique that would appear to offer advantages for reception of very low signal levels is receiver phase lock demodulation, presently being used in the Microlock and Secor systems. Theoretical improvements in excess of 50 db over conventional AM receivers are predicted. Improvement threshold of a standard FM/FM telemetry receiver has been lowered 20 db experimentally.

Improvement threshold of a receiver



BLOCK diagram of a basic phase lock demodulator. A frequency modulated signal is compared in a phase detector with a signal developed by a local oscillator, which is frequency modulated by the filtered output of the phase detector.

is that point on a plot of the signal to noise ratio where the ratio at the output of the receiver begins to degrade more rapidly than the input ratio. For conventional diode detectors in AM systems, this value is about −3 db input signal to noise ratio, while for conventional discriminators in FM systems the value is about +9 db. However when the ratio of deviation to maximum modulation frequency is greater than one, the output ratio for a given input is higher for FM than AM. This "wide band gain" property of FM offers considerable advantage for extremely long range communications.

Phase-Lock Demodulation

Receiver phase-lock demodulation operates on the principle that the optimum method of demodulation comprises the multiplication of an incoming signal by a locally generated best estimate of what the signal should be, and suitable filtering. This principle has recently been put to use by Radiation, Inc., which has developed an adaptor unit for standard FM/FM telemetry receivers which lowers the receiver threshold by at least 6 db.

In a paper delivered before the National Conference on Airborne Electronics last month, Hans Scharla-Nielsen of Radiation, Inc. said that the company has measured improvements of better than 20 db in special systems.

By this technique a frequency modulated signal is compared in a phase detector with a signal developed by a local oscillator which is frequency modulated by the filtered output of the phase detector, effectively lowering the receiver's improvement threshold.

Since, for all demodulation methods operating above their improvement thresholds, post-detection filtering is equivalent to predetection filtering, the wide band gain properties of FM may be utilized.

Space Trends

Avionics manufacturers studying the changes that space technology will press upon the industry will see increasing emphasis upon often heard themes—size, weight and power consumption.

The cost of developing microminiaturization techniques and avionic systems that will operate with 1,000 times the reliability of present day equipment while consuming only milliwatts or even microwatts of power will be more than compensated by the savings on each pound sent into space.

The enormously stringent demands of space technology will stimulate both improvements in conventional avionic techniques and—more important—research and development in totally new and unexpected fields that will be reflected in advances of the entire avionic art. ■

Power Sources for Space Explored

By James A. Fusca

Space vehicles soon to orbit earth as reconnaissance satellites, probe the far side of the moon, and eventually venture into outer space, will require steadily increasing amounts of electrical power from sources expected to last longer periods of time, weigh less and have less bulk.

Challenge of competing on the basis of technical competency and ingenuity as opposed to large capital investments in research has lured even some of the smallest avionics companies into competition with the industry's giants. Because the prize will be large government development contracts, no generation technique is being left unexplored as too unconventional.

Methods Under Investigation

For example, among the methods under investigation at present are:

• **Nuclear reactors.** Reactors small enough to be used as electrical power sources in satellites and other space vehicles presently are being developed by a number of major companies.

• **Radioactive isotopes.** Electric power can be generated with radioactive isotopes in at least two different manners. Charged particles emitted by some radioactive isotopes can be collected directly as electricity. Also, power can be produced by utilizing the heat produced when the emitted particles and electromagnetic radiation are absorbed.

• **Thermocouples.** With a constant heat source, multiple thermocouple junctions can be joined to produce up to several hundred watts with high voltage and low current or low voltage and high current.

• **Fuel cells.** Chemical energy of fuels can be converted directly to electrical energy without passing through the intermediate thermal and mechanical stages. Simple fuel cell could use electrochemical reaction of carbon and oxygen but the "indirect cell" which utilizes the gaseous reaction products of carbon and oxygen have the advantage of being capable of continuous regeneration to serve as a power source without shutdown or recharging.

• **Solar batteries.** Solar batteries utilizing silicon p-n junctions are the most efficient direct converters of solar energy at this time. Theoretical efficiency is 22%, and the actual efficiency about 10%.

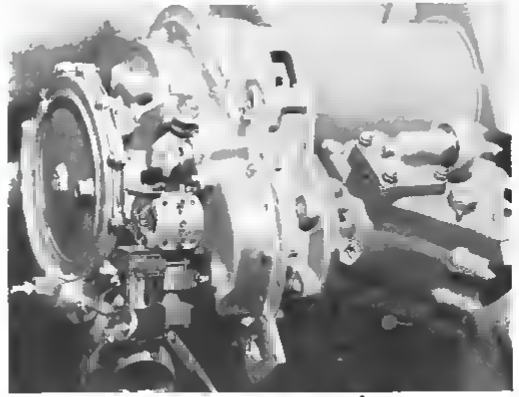
Other Methods

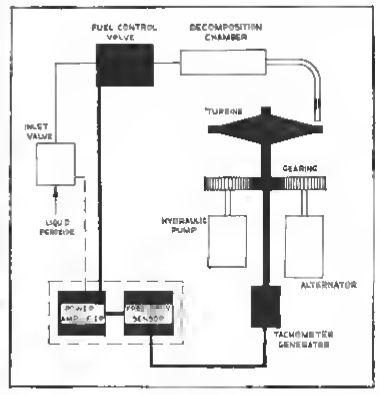
Less success has been found thus far with other unconventional methods of generating electric power, including:

• **Workman-Reynolds effect.** This effect is concerned with the development of

Performance of Unconventional Power Sources

Phenomenon	Theoretical Efficiency	Measured Efficiency	Weight per kw.	Volume per kw.	Volts	Current	Other
Ion Selective Membrane	85%		10^{2} lb.	2.9×10^{6} Cu. Ft	0.11v. on load	0.001a	50μw
Fuel Cell		60–75%	50 Lb./KWH (stored)		1 v/cell	1000 Amps/sq. ft	8 KW capacity Bacon Cell
Thermopile	56.6	8.75 7	4000	25	31	30	Wide selection in volts and amperes ratings
Oscillating Electro-Magnetic Induction		71			6	0.2	Wide selection in volts and amperes ratings
Photovoltaic (Solar)	22	11			3.5	150 amps/sq. meter	Silicon Cell 50 watts/sq. meter
Workmen-Reynolds Effect	14	0.004	90,000	3,000	230	10^{-4}	
Thermomagnetic			8,000				1.8 sq. ft./watt
Pyro-Electric						5×10^{-4}	
Emissive						0.01/sq. cm.	
Electrostatic	90				10^{7}	10^{-9}	
Electrokinetic Transducer		1.78×10^{-4}	2.82×10^{8}	1.88×10^{3}	300	0.01	
Piezo-Electric	90						10 watts/sq. cm.
Magnetostriction							





ELECTRIC-HYDRAULIC accessory power unit being developed by General Electric for the Atlas ICBM delivers closely regulated 400 cps electric power and 3,000 psi hydraulic power. Decomposing hydrogen peroxide drives unit as shown in diagram. In the photo, decomposition chamber and turbine are at far left, fuel control valve and gear box just to right. Driven accessories—alternator (a.c. generator), voltage regulator, and hydraulic pump—are at the center and right.

an electrical potential during the freezing of water. Charge separation effects that develop potentials as high as 230 volts occur between the frozen and unfrozen portions of an aqueous solution containing traces of inorganic impurities.

• **Pyro-electricity.** This is the term given to the potential generated between two faces of an oriented crystal when it is subjected to direct heating or electromagnetic radiation in the infrared spectrum, yielding a current of about 5×10^{-9} amp.

• **Thermionic emission.** Pure electron emission from solids that have been heated to incandescence can be considered the direct transmission of thermal energy into electrical energy. About the only practical application of this technique envisaged at present would be in locations such as an atomic pile where large amounts of waste heat might be utilized.

• **Ion permeable membrane.** Certain membranes have the property of permitting passage of ions only of one sign. The mechanism of conductivity similar to that in aqueous solution of electrolytes (by mobile ions). A battery can be constructed by assembling a group of cells so that a flow of ions takes place from the first to the last cell. This type of battery, however, is capable of producing only about 50 microwatts and, additionally, requires recharging.

With the exception of those depending upon nuclear reactions, the techniques mentioned have been investigated at the Oklahoma Institute of Technology under Air Force contract and the results described in two reports published by the Department of Commerce (PB 131411 and PB 131218, $2.00 each).

Several of the large avionics firms in this country are investing heavily in research on "miniaturized" nuclear reactors suitable for space vehicle use and capable of continuous operation for a period of years.

Less for reasons of security classification than because of the high cost of these programs and consequent protection of proprietary interests, companies have declined to discuss so much as their method of approach.

Some conclusions, however, can be drawn from the nature of the environment. Size and weight of any unit will be critical but cost will be less significant.

Engineers of Thompson Products Inc. have compared four potential approaches to the space vehicle reactor:

• **Rankine steam cycle.**
• **Closed gas turbine cycle.**
• **Mercury Rankine cycle.**
• **Rankine cycles with highly exotic fluids (rubidium, sodium or lithium).**

Rankine steam cycle is the basic cycle of conventional steam power plants except that in this case the heat conducted to the boiler is generated by a nuclear reaction rather than the usual fuel. Steam from the boiler drives a turbine which drives an electrical generator and a pump for returning condensed water to the boiler from the condenser.

Closed gas turbine cycle suffers from the disadvantages of low heat transfer coefficients, complex high temperature heat exchangers, large plumbing expensive compressor and turbine machinery, costly working fluid (if helium is used) in comparison with the Rankine cycle.

Mercury Rankine cycle has the advantage of being able to reject heat at relatively high temperatures and still maintain high cycle efficiencies, therefore requiring a relatively lightweight condenser and smaller sized reactor and heat exchanger.

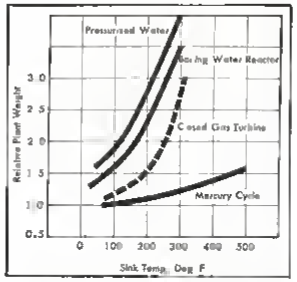
Rankine cycles utilizing more exotic fluids potentially will, when the equipment to handle them at very high temperatures is developed, provide even lighter weight units than the mercury cycle because of their ability to reject heat at temperatures greater than 1,000F.

On the surface of the earth where cooling air or water is available as a heat sink there is not a very large difference in weight between the different systems. In space, however, where waste heat will not be carried off by conduction but must be radiated to space from the skin of the vehicle a high radiator or sink temperature enables the designer to minimize the surface area and weight of the radiating skin.

Large Firms

Probably typical of the large firms presently in this field is General Electric Co., which says it is studying thermionic converters, thermoelectric converters, fuel cells, small nuclear power plants, solar converters, and radioactive isotopes.

Object they say is to make an intensive study of the practical applications for these sources of energy including their nature efficiencies limitations and competitive usefulness so that when requirements for space vehicle power sources arise the most advanced and



RELATIVE weights of nuclear power plants compared as a function of available heat sink temperature. On earth where cooling air or water are available as a heat sink there is no large difference in system weights. Above earth, where waste heat must be radiated high sink temperature is necessary to limit surface required.

most applicable methods can be chosen.

As one step in this direction the company has developed an accessory power engine consisting of a turbine and generator driven by decomposing hydrogen peroxide that has an operating cycle of 30 min., obviously intended for use with the Atlas.

Small Firms

One of the small firms that has entered into the competition is Radiation Research Corp., a firm with a background in the development of direct conversion nuclear batteries utilizing the isotopes radium, strontium, krypton and tritium.

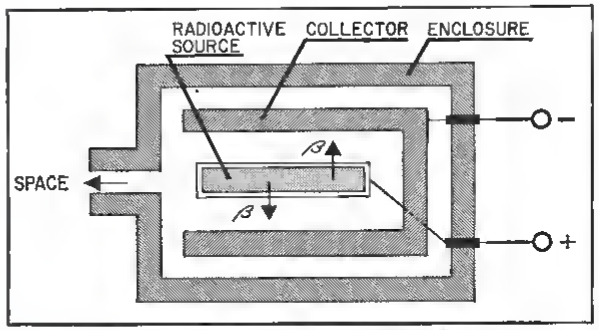
This company has proposed as a power source for space vehicles a direct conversion nuclear battery utilizing a vacuum dielectric—and that space itself which is a much better vacuum than is available here on earth be used as a perpetual vacuum pump.

Direct conversion is the process by which the charge particles from decay of radioactive isotopes are collected to develop a potential difference between the source and the collector which may be the outer casing of the battery. Isotopes used for direct conversion batteries give off beta particles (electrons) only.

Secondary conversion is a separate type of process by means of which the particles given off during radioactive decay are employed to excite phosphor light cells which in turn excite photovoltaic cells, or are absorbed and generate heat which acts upon thermocouples.

Principles of Operation

The proposed battery operates in much the same manner as more con-



DIRECT conversion nuclear battery proposed for space vehicles utilizes space as a vacuum pump to maintain vacuum dielectric. Battery would not operate until vehicle reached an altitude where outside pressure has fallen to 1/10,000 atmospheres.

ventional direct conversion batteries. The radioactive isotope is held in the center of the battery cavity by metal foil which is thin enough to permit at least 50% of the beta particles emitted to penetrate the foil and reach the beta particle collector.

Interior Cavity

The interior cavity of the battery is connected to the exterior of the vehicle by means of a tube. On the ground the battery will not generate electricity because air in the space between the radioactive source and the collector will be ionized by the radiation which will short circuit the battery.

As the vehicle is launched, however, the internal pressure will decrease with altitude. Generation of significant amounts of electricity will begin when the pressure has fallen below 1/10,000 atmospheres.

One disadvantage of direct conversion nuclear batteries is that they develop very high voltages with very little current. For example Ce^{144}-Pr^{144} has a beta particle distribution with a mean energy of approximately one million volts.

A second promising isotope Kr^{85} has a mean energy of 220 kilovolts.

This disadvantage, however, can be overcome by using a specially designed relaxation oscillator utilizing solid state devices as a d-c transformer. If the battery output is presumed to be 100,000 volts at 10 microamperes, this voltage can be stepped down to 100 volts at slightly less than 10 milliamperes with about 85% efficiency.

In practical terms, Ce^{144}-Pr^{144} fission product is available from the Atomic Energy Commission in the form CeO_2 which has a specific activity of more than .66 watts per gram after three years.

Assuming 50% of the radiated beta particles are absorbed by the radioactive material itself, a 25% battery collection efficiency, and an 80% conversion efficiency, the overall power efficiency is 10%.

Thus the power delivered to the load is 0.066 watts per gram or roughly 30 watts per pound at the end of three years.

Therefore, the power source has a capability of about 700,000 watt hours per pound.

If CeO_2 is used as a one millimeter thick source, more than one-half of the current is emitted from the two sides of the source. The total power in this case is five watts per square inch and the useful power, assuming an overall electrical efficiency of 10%, is 500 milliwatts per square inch. Theoretically, therefore a stacked battery of this type should be capable of delivering five watts per cubic inch of radioactive material.

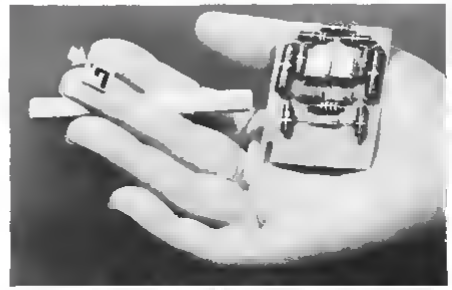
Kilowatt Source

Therefore, a one kilowatt source could be expected to occupy about five cubic feet of space, with allowance for dielectric spacing and collector plate volume.

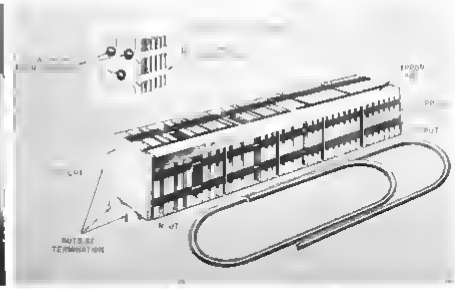
Advantages of the different types of nuclear power sources mentioned above has generated considerable interest on the part of companies presently preparing proposals for space vehicles and exploratory probes such as satellites to orbit the moon and transmit back data for periods of as long as a year.

Much additional research remains to be done, both on familiar systems of secondary power generation and on such new systems as may be uncovered with the present highly accelerated pace of scientific advancement.

While primary rocket power will be the force that eventually will put man in space, secondary power to operate equipment for keeping him alive and enabling him to function will be one of the keys to his eventual success. ■



MICRO-MINIATURE flip flop circuit (left), functional equivalent of circuit on right, employs novel printed-circuit transistors developed by Army's Diamond Ordnance Fuze Laboratories



RCA micro-modules, being developed for Army Signal Corps, consist of stack of 0.3 in. sq. modules, each consisting of ceramic plates containing flat transistors and other circuit elements.

Space to Spark Avionics Revolution

By Philip J. Klass

To meet the needs of space vehicles during the next decade, reliability of avionic equipment must be increased over present levels by a factor of at least 1,000, and its weight, size and power consumption must be slashed by a factor of 100, barring an unforeseen breakthrough in propulsion efficiency.

Magnitude of this challenge can be seen from the fact that all the intensive efforts of the past decade to improve reliability and reduce size and weight have resulted in gains of no more than a factor of 10.

Advance Is Required

A few examples illustrate why a giant step function advance is required in the state of avionic art

- **Reliability**—200 hr. of maintenance-free operation without failure considered more than adequate for aircraft where mission duration is 10 hr. or less, represents little more than a week's operating time for a space vehicle or satellite For many space vehicle applications, minimum of 10,000 hr. of trouble-free, zero maintenance operation will be required
- **Weight**—In modern high speed aircraft, price paid in increased gross weight per pound of avionic equipment carried is 10-20 lb. For a low orbit satellite using an efficient Vanguard-type launching vehicle, each pound of payload costs 1,000 lb. in launch vehicle weight To deliver the payload to Mars, the figure is approximately 12,000 lb. per pound of payload

Power consumption, which has been a low priority consideration in the design of aircraft avionic equipment in the past, now becomes a critical factor for space vehicles—at least until the advent of nuclear propulsion

These space vehicle needs are difficult to meet because the point of diminishing returns has been reached, using present technology Size of avionic components and assemblies has been squeezed down until further efforts threaten to turn avionics manufacturing into a jeweler's art It also appears unlikely that improved manufacturing controls and/or testing can boost reliability of present techniques by more than a factor of 10

Entirely new concepts in design and manufacturing now appear necessary to meet future space vehicle requirements This will require a fresh look at basic fundamentals of the problem to be solved, not merely an adaptation of former design approaches

New manufacturing techniques such as the fabrication of complete functional circuits of micro-miniature size by electro-chemical processes, instead of the use of conventional components, is typical of the kind of approach needed (AW June 2, p. 64) Major program to develop such "molecular circuitry" will soon be launched by Air Research and Development Command

Molecular Circuitry

Molecular circuitry approach includes the design of semiconductor devices which can perform functions that previously required a complex circuit For example, a new semiconductor decade counter under development by Bell Telephone Laboratories and Radio Corp. of America—hardly larger than a single transistor—promises to perform the same circuit function that previously required 80 individual components, including 20 transistors

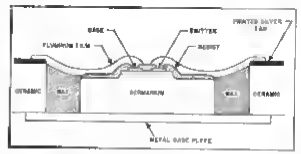
Avionic designers will find the new space environment permits certain shortcuts just as it presents new problems For example, hermetic sealing of devices may not be required because the space environment offers a better vacuum than can now be achieved by the best available factory evacuation techniques However, newly discovered intense radiation at altitudes above 600 mi. (AW May 5, p. 39) raises shielding problems for semiconductors and other circuit elements

Small Quantities

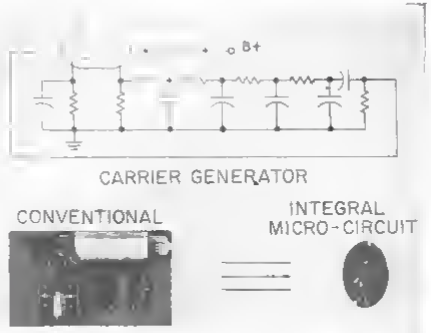
Fortunately for the avionic equipment designer, number of space vehicles likely to be launched during the next several years will be relatively small and these will be able to accommodate only a modest amount of avionic equipment This makes it feasible to fabricate circuitry under a microscope and to use intensive monitoring and testing to improve reliability.

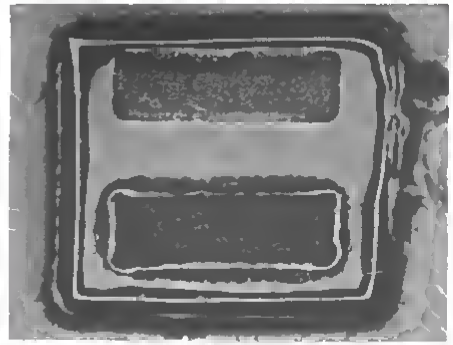
A number of companies and agencies have micro-circuitry developments under way Three approaches representative of the variety of techniques under investigation are

- **Army's Diamond Ordnance Fuze Laboratories** (DOFL) has developed micro-circuitry fabrication techniques that permit volumetric densities of



SIDE VIEW of Army transistor shows it integrally mounted without case in ceramic plate and connected to circuitry.





NOVEL APPROACH to micro-circuitry (left) is vacuum disposition process used by Varo Manufacturing Co. to produce functionally integrated circuit in a single series of operations. Carrier generator size, weight is cut 95%. Far greater gains than these appear possible. Transistor (right) made by Army printed circuit process, looks like this when enlarged 300 times. One bar is base electrode, the other is emitter. Collector is below

about 1,000 components per cu in., including 200 transistors, compared to 50-100 components per cu in. which is best obtainable today with conventional components and techniques. Further research may increase volumetric density to as high as 10,000 components per cu in. DOFL scientists believe:

- **Radio Corp. of America,** under Army Signal Corps contract, is developing "Micro Modules" which bear some resemblance to Navy's Tinkertoy construction.

They are expected to yield volumetric efficiencies of 300 to 400 components per cu in. RCA says this will provide up to 90% reduction in size and nearly as much in weight over present subminiature construction.

- **Varo Manufacturing Co.,** under Office of Naval Research sponsorship, is experimentally fabricating complete functional circuits (except for transistors) by evaporative depositing technique. Company officials predict their micro circuitry technique can achieve equivalent of 100,000 components per cu in., perhaps as many as 1 million per cubic inch eventually, with very significant reductions in weight. Servo mechanisms, Inc., also is working with evaporative deposition techniques for making components and circuit elements.

The Diamond Ordnance Fuze Laboratories program, currently in the pilot production stage, has contributed at least two advances in micro-miniaturization fabrication art:

- **Concept of mounting** uncased transistor crystals integrally with associated circuit elements on tiny printed circuit plates, with complete assembly subsequently encapsulated for protection against contamination.
- **Photolithographic process** for making transistors which lends itself to mechanized production.

When the transistor was first developed it was so much smaller than the vacuum tube it replaced that no one worried about the fact that the semiconductor crystal forming the heart of the device actually occupied less than 5% of the total volume—the rest consisting of case, base, crystal support leads and vacuum or inert gas.

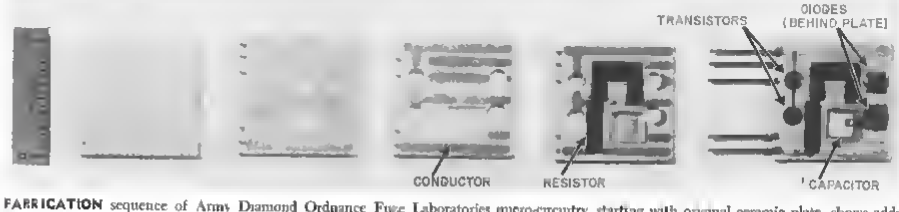
In seeking ways to achieve further miniaturization for fuze applications, DOFL scientists concluded that the transistors—even with the more recent miniature size cases—had become a limiting factor to further gains in size and weight reduction.

Transistor enclosure, crystal supporting frame and leads are eliminated and the semiconductor crystal is mounted directly in a tiny hole in the printed circuit plate, like a cork in a bottle. Transistor elements (emitter, base, collector) are then electrically connected to adjoining circuit elements by means of thin aluminum conductors laid down by evaporative deposition process, according to Dr. J. W. Lathrop of the Fuze Lab.

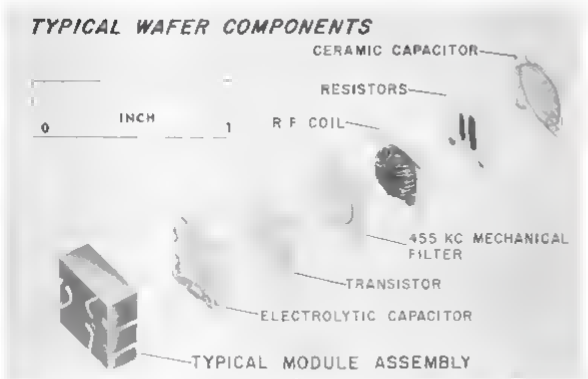
Micro-Circuit Elements

Tiny steatite ceramic plates, smaller than an adult's thumb nail, serve as a base for construction of DOFL's micro-circuitry. Plate measures ½ x ½ in. and is 0.02 in. thick. Conductors are produced by a silk screen process using silver paint, which is then permanently fixed to the base plate by oven firing. Resistors also are produced by silk screen process to within 20% of desired value.

Capacitors are produced on separate blanks, measuring only 0.1 in. square. Blank material is selected according to



FABRICATION sequence of Army Diamond Ordnance Fuze Laboratories micro-circuitry, starting with original ceramic plate, shows addition of silk-screen produced conductors, machining, addition of resistive material, finally transistors, capacitors



ALL POSSIBLE components used in RCA micro-modules will be fabricated with flat form factor directly onto small ceramic plates which are later stacked, connected into circuit

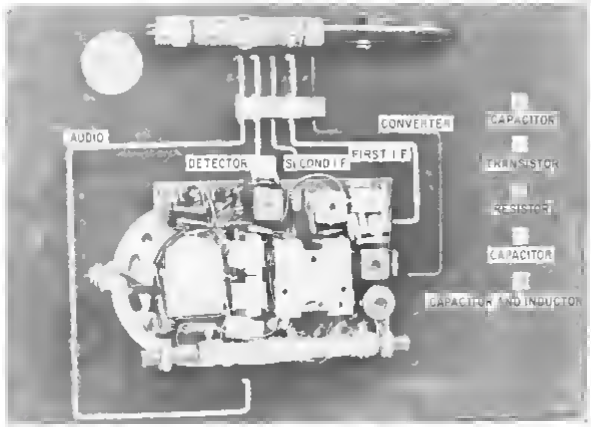
dielectric constant required for value of capacitance Silver paint laid down by silk screen process produces capacitor plates Capacitors are then flush mounted in small indentations machined into the larger circuit base plate

At present 0 01 mfd is the largest capacitor that DOEL produces but these can be flush mounted in a brick to brick fashion to double this value or interconnected to give higher values Flush mounting of capacitors is a space saving feature which permits resistive elements to be placed on top of a capacitor

Producing inductors particularly in larger values remains one of the major unsolved problems in DOEL's micro circuitry approach according to Lathrop

This limits the technique to circuits which require only resistors capacitors transistors and diodes, such as RC coupled amplifiers, digital computer flip flop and binary counters Technique also is limited to low power/current applications and to circuits where tolerances on individual component values are not critical American Bosch Arma Corp, one of several companies investigating the DOEL technique believes it may enable the company to slash size and weight of Titan guidance computer by factor of 10 over best obtainable with present subminiature construction

Photolithographic process for fabri



MINIATURE transistor radio receiver (below) of conventional construction can be squeezed into a fountain pen size container (above) using RCA's micro module construction.

citing transistors is not limited to units intended for micro-circuitry. Number of transistor manufacturers are currently experimenting with the process for possible use in making conventional semiconductors. Although problems remain, the technique holds promise of a moderately low-cost, mass-production method for making semiconductor devices.

DOFL has successfully used its photo-etch technique to produce P-N-P diffused base germanium transistors, capable of operating in medium frequency range. Current investigations indicate the technique may be even easier to apply to silicon devices, although none has yet been made by DOFL.

Starting with thin P-type germanium blanks (0.045 in. sq. by 0.01 in. thick), into which arsenic has been diffused to provide a thin (9 microns) layer of N-type germanium on one surface, a coat of photo-sensitive material is laid down on the N-type surface. This is exposed to ultra-violet light through a mask or photo-negative containing a rectangular-shaped pattern with length-to-width ratio of about 3 to 1. Blank is then dipped into developer solution, which removes rectangular shaped area of the photo-sensitive coating.

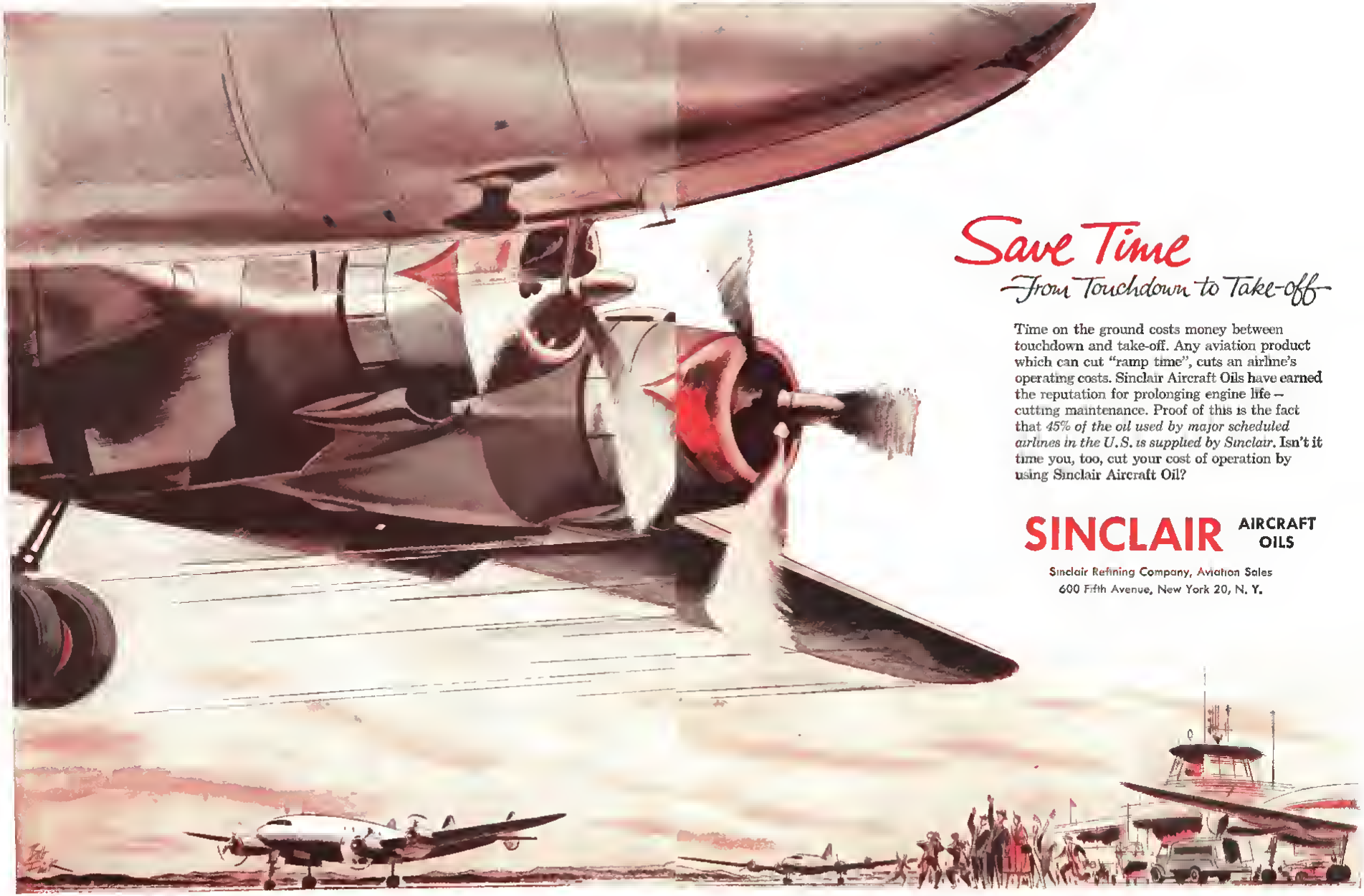
Next the blank is exposed to aluminum vapor which deposits over entire surface, making contact with N-type germanium layer only in rectangular area previously etched away. Remainder of photosensitive coating is removed and blank is heat treated to form alloy junction between aluminum rectangle and the N-type germanium to produce the transistor emitter.

Similar process is used to lay down a parallel rectangular area of gold (with small amount of antimony added) to form the base electrode. A third etching operation removes unwanted portions of the N-type layer, leaving a pedestal which supports the two parallel rectangular shaped deposits.

When the device is viewed from the side under a microscope it resembles a railroad track on a gravel roadbed. The base and emitter resemble the two tracks, the remaining pedestal of N-type germanium layer resembles the gravel roadbed, while the thick P-type germanium collector resembles the earth. (See sketch, photos.)

Similar photo-etch processes are used to deposit thin aluminum conductors which connect transistor electrodes to other circuit elements after transistor crystal has been mounted in steatite circuit board.

Maximum alpha cut off frequency of the several dozen transistors produced to date by DOFL is about 20 mc., but figures as high as 600-800 mc. may be possible, according to James Nall. Operating frequency can be increased by reducing width and length of the rec-



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tangular electrodes. These already are down to about 0.01 in. Further reductions are possible, but not easy, because of problems of grain size in photolith negatives and maintaining registry. Another possibility is to use different electrode shapes and this is currently under investigation.

Same basic technique can be used to produce semiconductor diodes, with a circular electrode on a circular pedestal instead of rectangular configuration used in transistor.

RCA's Approach

Radio Corp. of America's approach to micro-circuitry for the Signal Corps program will use combinations of 0.3 in. sq. modules of varying thickness, depending on the function of the module's circuit. Each module in turn will consist of an electrically interconnected stack of 0.3 in. sq. ceramic wafers, 0.01 in. thick, each containing one or more components (see sketch, p. 246). There will be provision for shielding or isolating individual wafers as required.

RCA's wafer module bears some resemblance to the Navy Tinkertoy module but RCA wafers will have only about one-ninth as much surface area.

Wherever possible components will be fabricated directly on the thin ceramic wafers. This will include transistors, diodes, capacitors and resistors. A few components such as larger inductors may be fabricated separately and then mounted on a wafer.

Fabrication of individual wafers and complete modules is "ideally suited for automatic manufacturing with completely controlled processes," according to B. V. Dale, chief engineer of RCA's components division.

Company already has built experimental samples of a complete broadcast radio receiver in a fountain pen size container using new micro-circuit modules.

Here is brief run-down of RCA's planned approach to fabrication of components for its micro modules:

• **Transistors**—RCA's Semiconductor Division has produced samples of a flat alloyed transistor construction which appears ideal for wafer configuration.

• **Resistors**—Investigations to date indicate that both carbon composition and highly stable carbon or metal precision quality resistors in values ranging from 10 ohms to 1 megohm can be produced on the tiny wafers.

• **Capacitors**—Using wafers made of controlled temperature coefficient materials as a dielectric it is possible to produce precision capacitors with values of 1 to 100 mmfd. For higher capacitance values RCA is developing processes for depositing thin dielectric films on the wafer. Company has produced capacitors with values up to 1 mfd. by these techniques. Investigations to date indicate that wafer type electrolytics can be

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The brittle cold of the stratosphere . . . the heat of air-skin friction . . . the acceleration and vibration of launch and flight . . . the unfavorable conditions inherent to storage and handling . . . all these factors can play havoc with a guided missile.

Hughes Research and Development engineers have designed the Falcon air-to-air guided missile to operate under the most severe conditions. Environmental testing (see Sand & Dust Test at left) subjects missiles to extremes in temperature, shock and other trouble-making conditions.

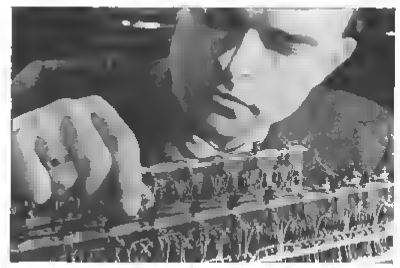
The Falcon missiles, with either infrared and radar guidance systems, measure only about 6½ inches in diameter. Complex guidance, control and auxiliary systems of each missile are installed in a space no bigger than a stovepipe.

The research and development skill required to successfully engineer the Falcons typifies the challenge present today in other Hughes guided missile assignments of a more classified nature. A few of the areas being emphasized by the Hughes Research and Development Laboratories include missile launchers and power plants, guidance systems, reliability, product design, microwaves, aerodynamics, field test and telemetering, stress analysis and related areas.

High orders of engineering skill are also manifest in other Hughes activities. The commercial area, Hughes Products, has recently announced the development of a numerical control system which will automate a complete and integrated line of machine tools. The Hughes Ground Systems Division has developed a radar antenna which provides three-dimensional target data from a single antenna, transmitter and receiving channel.

Apart from the diversity of activity and the highly rewarding type of work, prospective employees may have confidence in the fact that Hughes will retain its leadership in the field of advanced electronics.

Collapsing the time between missile development and its effective tactical use is a project assigned to the Hughes Tucson Engineering Laboratories.



So advanced is the test equipment being designed by Hughes engineers in the El Segundo Manufacturing Plant that the test equipment is often as complex as the advanced systems being tested.

An immediate need now exists for engineers in the following areas

Circuit Design	Computer Engineering
Reliability	Crystal Filters
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• **Inductors**—Toroidal windings using ferromagnetic cores will be used to minimize spurious radiation and coupling problems. Inductance values ranging from fractions of a microhenry to as high as 10 mh in wafer sizes appear realizable. To eliminate need for large audio inductors and transformers, RCA expects to make use of complementary symmetry techniques in application of transistors.

• **Tuning elements**—Reverse biased semiconductor diode appears to be the most promising approach to tuneable elements because it is extremely small, has negligible temperature coefficient and hysteresis according to Dale.

RCA's current $5 million Army contract, which runs for two years, is expected to bring its micro-module program to the point where pilot production models can be fabricated.

Although RCA's immediate goals require the use of more or less conventional extensions of existing component techniques, the micro-module concept is broad enough to incorporate new concepts in complete solid state circuits which might be developed in the future, according to O. B. Cunningham, chief engineer of RCA's Surface Communication department.

Varo Micro-Circuitry

One of the most ambitious and futuristic approaches to micro-circuitry is that being developed by Varo Manufacturing Co., a Garland, Tex., avionics manufacturer. Company began active investigation of use of vacuum depositing process for fabricating complete functional circuits about two years ago. Office of Naval Research took over program sponsorship about a year ago because the technique looked like a promising way to reduce size and weight greatly and improve reliability of an airborne digital computer required for ONR's integrated cockpit display program.

Varo now works closely with Servomechanisms, Inc., whose scientists are developing new materials for possible use in the latter company's program to produce extremely high temperature components by the vacuum depositing process. (AW Sept. 30, 1957, p. 70.)

In the evaporative depositing process, a conducting, semiconducting or dielectric material is heated to its vaporizing temperature under a high vacuum. The vaporized material then deposits in a thin film on a suitable substrate (base). Shape of the film deposited can be controlled by placing a mask of desired shape between vapor source and substrate.

Another possibility currently being investigated by Varo is to charge the vapor particles, then use a magnetic field to deflect the ion beam to trace out

the desired pattern on substrate—similar to use of a magnetic field to deflect electron beam in a TV tube.

Structure of the thin film can be controlled by the choice of substrate material and/or its surface temperature. This suggests that it should be possible to produce transistors by the same process. Both Varo and Servomechanisms have produced semiconductor diodes by evaporative depositing process and it appears to be just a question of time until field effect transistors can be fabricated the same way.

Complete Circuits

Varo's work is aimed at producing integrated functional circuits by vacuum deposition rather than merely fabricating a collection of individual components. As a result it not only achieves major size and weight reduction but frequently ends up with improved circuit performance.

For example in many filter networks it is possible to improve performance characteristics if network is constructed of an infinitely large number of conventional components (distributed constants). But because of cost, size and weight considerations the circuit designer compromises for a less idealized network using far fewer elements (lumped constants).

In producing an RC network, Varo can deposit patterns of conducting and resistive films on opposite sides of the substrate so they jointly perform like a distributed constants network. This is actually easier and less costly than producing the less desirable lumped constants network.

Varo has developed techniques which make it possible to simultaneously evaporate several different types of material, mix and deposit them on the substrate in controlled proportions. This "molecular metallurgy," as Varo refers to it, permits the alloying of materials with widely different vaporization temperatures—something that cannot be done by conventional metallurgical processes.

Molecular metallurgy opens the way to creating new types of materials that for example, can be used to produce resistors with linear or non linear characteristics with a variety of temperature coefficients according to Jack Smith, Varo's vice president of engineering.

In the course of developing molecular circuitry fabrication techniques, Varo has produced an interesting variety of experimental integral circuits. Although Smith emphasizes that there has been no attempt to achieve maximum possible miniaturization at this stage, notable size and weight reduction already has been realized. Representative circuits that Varo has produced include a Carrier generator (RC oscillator) originally consisting of eight resistors, six capacitors and a subminiature tube has

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been duplicated by molecular circuitry techniques with approximately a 20 to 1 reduction in size and weight. Improved performance obtained with distributed constants network permits use of transistor instead of subminiature tube used in original version.

• **Eccles-Jordan binary counter,** originally employing seven resistors, four capacitors and two transistors has been reproduced entirely by vacuum deposition except for two transistors.

• **DC amplifier,** consisting of four transistors and 12 resistors.

Improved Reliability

By eliminating most of the soldered interconnections required in conventional construction Varo believes it will get rid of a major source of unreliability. An even more important reliability gain should result because of the inherent cleanliness of the evaporative deposition process. Fabrication takes place under vacuum at elevated temperatures. Process of "boiling" the working material, like distillation of water, tends to separate out many unwanted impurities in the working material. It also is possible to use techniques such as those employed in mass spectrometers to segregate unwanted elements in the working material vapor.

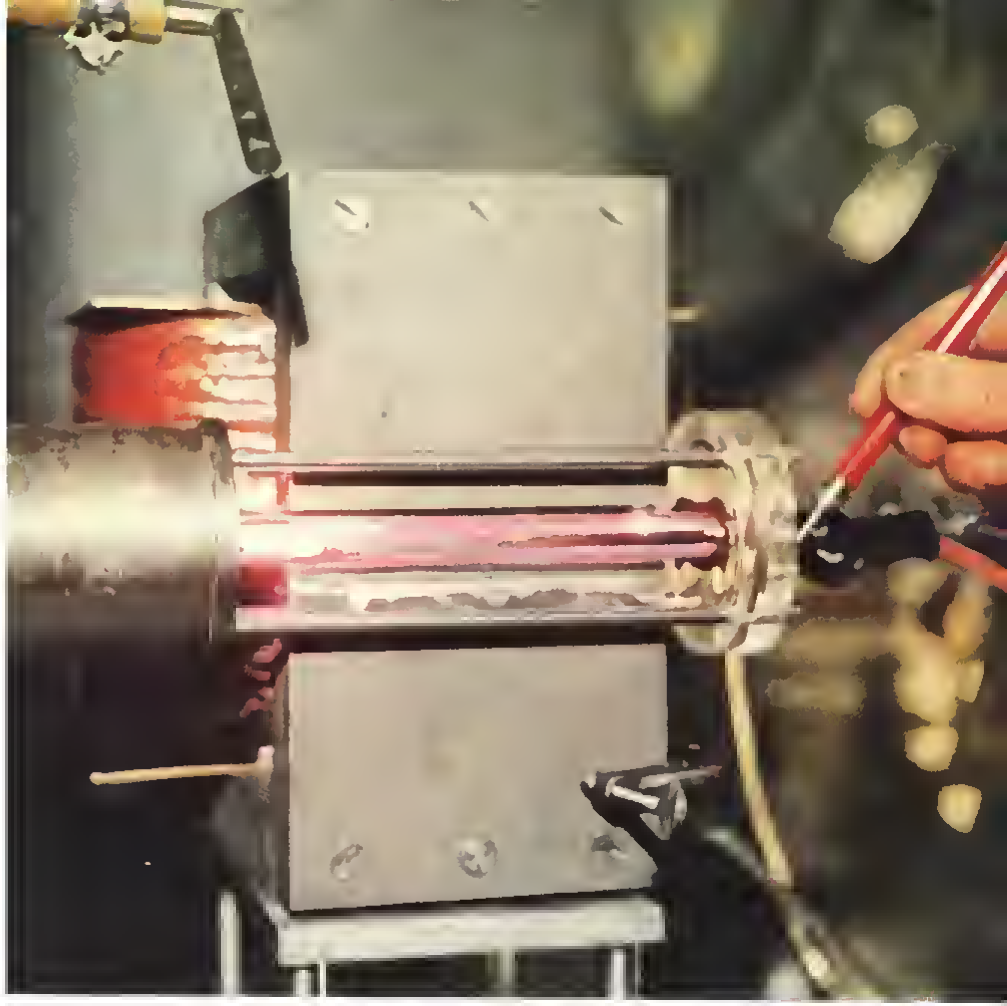
Industry Impact

Whether the evaporative deposition or some other process ultimately proves best for fabrication of molecular circuitry, there can be little doubt that the impact of this new concept will be felt throughout the electronic industry—including consumer products.

The molecular circuitry could upset traditional lines of demarcation between component and equipment manufacturers. Because it is a direct threat to conventional components, component manufacturers may be expected to consider developments of this sort.

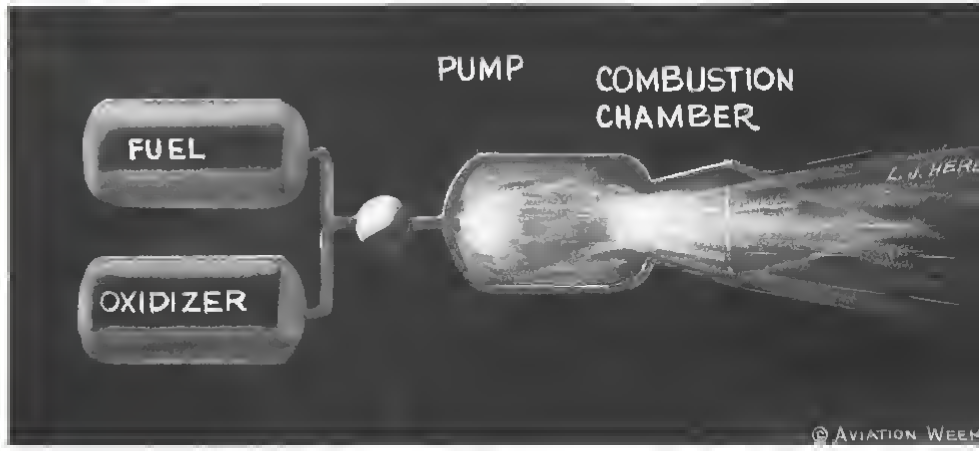
However, development of molecular circuitry will require more investment in long hair basic and applied research than many small component makers can afford. It also will require considerably more knowledge of circuit design than at present. Perhaps a number of smaller component makers will take a leaf from the book of medium size avionic equipment manufacturers who are now forming teams for pooling of funds facilities and manpower to submit joint proposals on projects too large for any one firm to handle.

Major efforts probably will be earned on by major equipment manufacturers, many of whom also are heavily engaged in component and semiconductor work, such as American Telephone & Telegraph Co., General Electric Co., International Business Machines Corp., Hughes Aircraft Co., Philco, RCA, and Texas Instruments Inc. ■



ION ENGINE operates in National Advisory Committee for Aeronautics' Lewis Flight Propulsion Laboratory.

Propulsion



CONVENTIONAL propulsion methods account for 90% of the money and effort devoted to rocket propulsion research and development.

Advances Made in Conventional Fuels

By Michael Yaffee

Over 90% of the money and effort actually going into rocket propulsion research and development is being spent on the improvement of conventional propellants and engines rather than on the development of radical, new powerplants. The goals of the researchers are comparatively modest. They are:

- **Development of storeable liquid propellants**
- **Increased grain size in solid propellants**
- **Production of liquid propellants that can be substituted in present engines without major hardware modifications**
- **Greater thermal stability in solids**
- **Propellant combinations tailored to specific engines**
- **Increased density.**
- **Higher specific impulse.**

Significant Advance

Some significant advances toward these goals have already been made. A striking demonstration of this, for example, was the launching earlier this year of the first United States artificial satellite, Explorer I. The modified Redstone missile used as the first stage of the carrier rocket burned a mixture of liquid oxygen and Hydyne in place of its usual mixture of lox and alcohol.

Hydyne, developed by North American Aviation, is a 60-40 mixture of unsymmetrical dimethylhydrazine and diethylene triamine, which also goes by the more general name of UDETA. Substituted for alcohol with only minor modifications in hardware, the new fuel increased thrust by about 12%.

But as a substitute fuel, UDETA is limited for the most part to propellant combinations containing alcohol. The specific impulse of the lox-UDETA system, about 270, is not a great enough increase over the 266 of lox-RP-1 combinations to consider UDETA as a replacement for the hydrocarbon fuels. Even if it were, there is the important consideration of physical properties. For one fuel to replace another in an existing missile, the substitute must have the same density and mix with the oxidizer in the same ratio as original.

If all these conditions (and others such as cost and compatibility of chemical characteristics) could be met by a new substitute fuel that offered higher specific impulse, then the military is definitely interested. But the chances of this happening are fairly remote. Other than UDETA, the only candidates mentioned for substitution so far are the following fuel combinations: hydrazine and RP-1, unsymmetrical dimethyl hydrazine and JP-4, and hydrazine and UDMH.

For solid propellants, the problems of substitution are much less severe because of the absence of most of the plumbing (i.e., fuel tanks, piping, valves, etc.) associated with liquid engines. By the same token, there would be little need for substitution since it would be almost as simple to build a new engine.

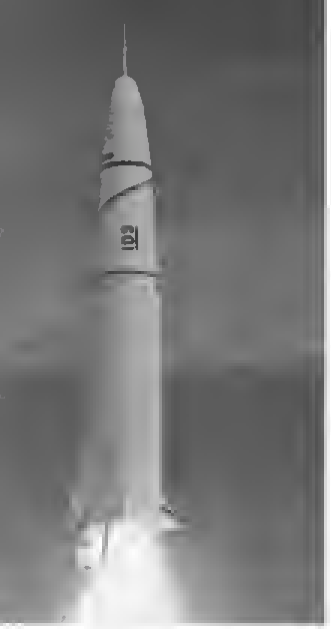
As the production and testing of rocket engines increased and as the engines themselves grew in size, the military decided that it was necessary economically and logistically for the large rocket engines to burn cheap, easily available hydrocarbon fuels.

But as the engines improved, their fuel needs became better defined and more stringent. The need now is for fuels tailored to fit specific engines.

JP-4 will continue to be the major fuel for years to come, according to Ben P. Wilkes, Aeronautical Research Administrator, Headquarters, USAF. But JP-4 is a fairly wide-cut kerosene, containing comparatively numerous impurities and in many ways inadequate for even the present generation of rocket engines. Interested in improving the undesirable characteristics of JP-4, researchers have come up with a number of new hydrocarbon fuels.

Among the more significant of these new hydrocarbons are JP-6, JP-6H and RP-1. JP-6 is a wide petroleum cut with increased thermal stability and less severe freeze point requirements. In an effort to define more closely the properties of JP-6, the researchers came up with a very narrow cut called JP-6H (H stands for heart cut) which has a more closely defined boiling range and performance characteristics. In RP-1, a relatively light cut hydrocarbon, most of the contaminating aromatics have been eliminated with a resultant increase in thermal stability of the fuel.

All of these newer hydrocarbon fuels were developed to meet the growing



THOR IR&M is shown shortly after takeoff at Cape Canaveral, Fla.

thermal stability demands being placed on these fuels as a result of their secondary role as thrust chamber coolants. In addition to thermal stability, these petroleum based fuels, according to Wilkes, must have a negligible tendency to deposit coke during flow through the cooling passages. This would produce local hotspots and result in thrust chamber burnouts.

The future program in this area, says Gulf Research & Development Co.'s Robert A. Wells, calls for a more thorough examination of alkylated derivatives of basic polycyclic structures such as Decalin and Perhydrofluorene. In addition to raising heating values per unit volume above those of JP-4 and JP-6, alkylation of the polycyclic hydrocarbons raises their heating value per unit weight to a level comparable to that of JP-4 and JP-6 and lowers their freezing points and their viscosity.

Wells, however, feels that the high density hydrocarbon fuels of these types together with JP-6, JP-6H and RP-1 will make up only a very small part of the total military fuel requirements in the foreseeable future. At the same time, Wells, agreeing basically with Wilkes, sees JP-4 not only as the highest volume product but actually surpassing aviation gas by 1960.

One of the most significant events in the solid propellant field has been the recent announcements by Olin Mathieson Chemical Corp. and Callery Chemical Co. that they have under development a high energy solid borane rocket propellant. While these two programs may lead to the first major breakthrough in the high energy solid field, the propellants themselves are considered at least one missile generation away.

Another important development was the static firing earlier this year of two large solid propellant engines, one by Thiokol and the other by Aerojet General. The Thiokol engine contained over 10 tons of propellants, significantly more than any earlier solid engine. Like the solid borane rocket, these large solid propellant engines are not slated for use in the present generation of missiles. Both programs, however, define important areas for continuing research in the solid propellant field.

On the hardware side, work is continuing on the improvement of thrust vector control and thrust termination in solid engines. While not a hardware problem, the long sought after development of large solid grains referred to above, is more of an engineering puzzle than a true research problem. The difficulty here lies in the manufacturing methods which still fall short of perfection when it comes to casting large grains.

Solid Propellant Problem

Another problem associated with solid propellants and requiring continuing development effort is their temperature sensitivity. The burning rates of most solid propellants increase by 0.05 to 0.2% per degree increase in initial temperature. As a result, the performance of the engine is dependent on the storage temperature. Difficulty in controlling burning rates is reported to be more of a problem with the polyurethane fuels than with the older polysulfide elastomers.

Another potentially rewarding area for investigation in solids concerns the oxidizers which make up as much as 80% of the total propellant weight. Of late, lithium perchlorate has been getting a great deal of attention because of its high percentage of available oxygen. But the compound is hygroscopic and comparatively expensive. Consequently, ammonium nitrate still holds sway among solid oxidizers.

Double-base propellants, whose popularity has dropped off sharply in the past decade, offer another means of improving the position of solids, according to Hercules Powder Co., a major government contractor in this field. To prove its point, the company recently started building its own facility in Utah, in which it will carry out research and development on double base propellants.

Perhaps the most pressing current need in liquid propellants, according to top Air Force and Defense Department officials, is for logistic simplicity comparable to that of solids. This means monopropellants or storeable bipropellants.

(The reason for the large scale research and development effort in this area is twofold: 1. First U.S. ballistic missiles, which will be the active and probably the only such weapons available for the next five years, are committed to liquids; and 2. While they don't generally broadcast the fact, many top military people prefer liquids because of their inherently higher energy potential.)

On the whole, monopropellants have not proven very attractive in this country (as compared to England). They possess either low specific impulse or, as this goes up, poor handling characteristics. For the last few years, however, there have been monopropellant symposiums at which large numbers of propellant men discuss information that might lead to new, higher energy liquid monopropellants.

The only development of note is the research work Phillips Petroleum is currently carrying out for the Air Force on storeable high energy monopropellants. Phillips says it is making good progress and believes that the monopropellants it is working on could increase reliability with practically no sacrifice in the performance offered by present bipropellant systems.

The bulk of the research effort in this area, however, is currently concentrating on storeability, which appears to offer a great deal more promise. And, as with substitution, this research road leads back to hydrazine and its derivatives.

Actually, the difficulties here lie more with the oxidizers than with the fuels. Most fuels are storeable, some, such as UDMH, more so than others, such as hydrazine. On the other hand, lox, which is the major liquid oxidizer, can't be stored because of its low boiling point. To get around this, lox generally is generated at the launching site and continually topped off, necessitating both an unwieldy complex of ground support equipment and a fairly long count down.

There are some liquid oxidizers—notably red fuming nitric acid (which is generally inhibited with hydrogen fluoride), nitrogen tetroxide, and mixed oxides of nitrogen—which have been under study by the Jet Propulsion Laboratory and similar research centers and which show good storeability.

When the military first decided to

High Energy Fuels for Rocket Engine

Performance Comparisons

● P_c = 500 Psia ● Frozen Equilibrium ● Optimum Expansion

	OXIDIZER	FUEL	I_{sp}
LIQUIDS	6r F_2	NH_3	236
	LOX	JP-4	264
	LOX	RP-1	266
	LOX	N_2H_4	282
	LOX	H_2	364
	F_2	JP-4	282
	F_2	$N-H_4$	316
	F_2	H_2	374
	O_2	JP-4	293
	O_2	H_2	393
	LOX	UDETA	270
STOREABLE LIQUIDS	13FNA (22% NO_2)	UDMN	250
	N_2O_4	N_2H_4	263
	N_2O_4	UDMH	255
	ClF_3	N_2H_4	255
	ClO_3F	N_2H_4	258
	N_2O_4 (18% NO)	UDETA 60% UDMN 40% BETA	260
SOLIDS	NH_4ClO_4	Plastic Rubber/Metal	to 275
	B/O F/N/Cl	H_2/B/Al/C	to 400

shift its large liquid rocket engines to the less expensive hydrocarbon fuels, it ran into difficulties with the engines using nitric acid as the oxidizer. It appears that the nitrogen-based oxidizers such as nitric acid and nitrogen tetroxide perform better in association with nitrogen-centered fuels such as hydrazine.

A number of liquid combinations now under development show a great deal of promise as storeable propellants for the near future. Of these says Wilkes, the three most promising appear to be inhibited red fuming nitric acid with UDMH, nitrogen tetroxide with hydrazine, and mixed oxides of nitrogen with UDETA.

When the Air Force talks storeability, it is talking in terms of years. As far as performance goes, it will settle for storeables with capabilities comparable to those of present liquid systems. How far away are they? According to the Air Force, storeable liquid propellants are "about neck-an-neck in the state-of-the-art with the large solid propellant rocket engines" and the Air Force considers one program as the back-up for the other.

Quest for Power

Specific impulse is important, particularly for the long range missiles. Raising I_{sp} from 250 to 265 for example, could increase the range of an ICBM almost 50% and that of an IRBM 20%.

But the principal interest in developing higher energy propellants doesn't stem from any desire, or need, for greater range. Missile men are more interested in increasing specific impulse in order to reduce the amount of propellant required by a missile and, hence, the size of the missile. Increased specific impulse also means greater payload capability and increased velocity. In small air-to-air missiles, higher energy propellants could mean smaller airframes, less drag and increased velocity. For the large intercontinental ballistic missiles, particularly for second or third generation missiles, increased power will mean flatter trajectories and faster re-entry.

At present, specific impulse runs from about 240 to 265 for both solids and liquids. Within the realization of current technology, the top specific impulse attainable is about 393 from a combination of liquid ozone and liquid hydrogen. Liquid ozone, however, is unpredictable and hard to handle and the system itself is a good distance away from any operational capability.

Much closer to realization is a liquid fluorine-hydrazine system (with the possibility of substituting UDMH, UDETA or ammonia for the hydrazine). This system will give a specific impulse of approximately 316. Both Rocketdyne and Bell have been firing small, experimental engines with these mixtures and claim that they are ready to scale up as soon as the military will give them the go-ahead and the money. The Air Force, while interested in the project, disagrees. The corrosive nature of fluorine and its combustion products

creates problems in regard to materials of construction for combustion chamber and pumps and in regard to lubrication of moving parts in the pumps that the companies still haven't solved to the satisfaction of the Air Force. The fluorine rocket one propellant man declares, is at least five years away.

In combination with liquid hydrogen, liquid fluorine will produce a specific impulse of 374. This brings up two interesting qualifications of the quest for high energy propellants. The first is that the biggest energy pay-off will come from research in oxidizers and not in fuels. Second, specific impulse by itself is a much less significant factor than specific impulse times density.

Impulse Comparison

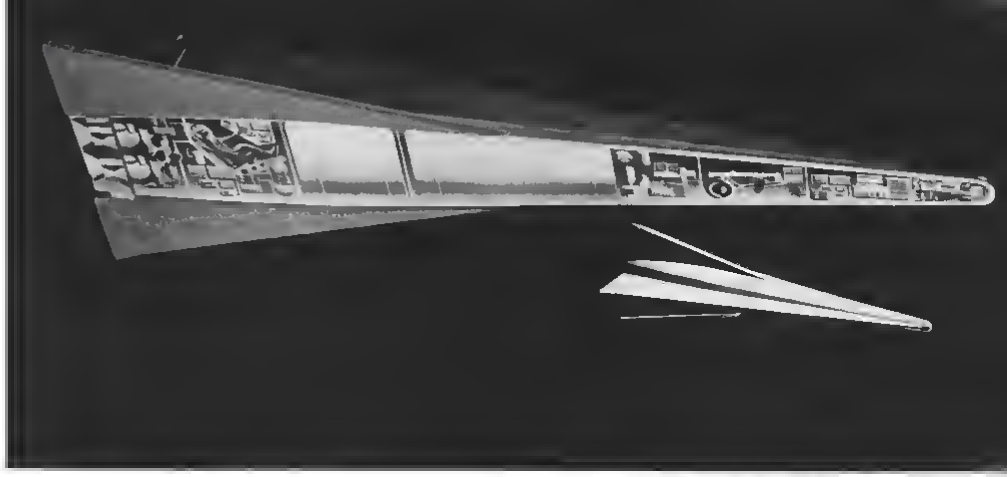
Compared on this basis of specific impulse times density, the hydrogen-fluorine combination checks out at approximately 250 gram seconds per cubic centimeter while the hydrazine-fluorine propellant measures over 400. The combination of bromine pentafluoride and ammonia checks out even higher on a density impulse basis (about 440) but handling and other problems associated with the use of the bromine oxidizer have pretty well dimmed the outlook for this particular combination.

In regard to the development of high energy solid propellants, Ben Wilkes says, attempts need to be made to synthesize compounds with double or even triple bonds and to make compounds with boron and aluminum as an integral part of the molecule. Compounds such as these he says show (calculated) specific impulses up to 400.

This work however is still in the "interesting possibility" stage only.

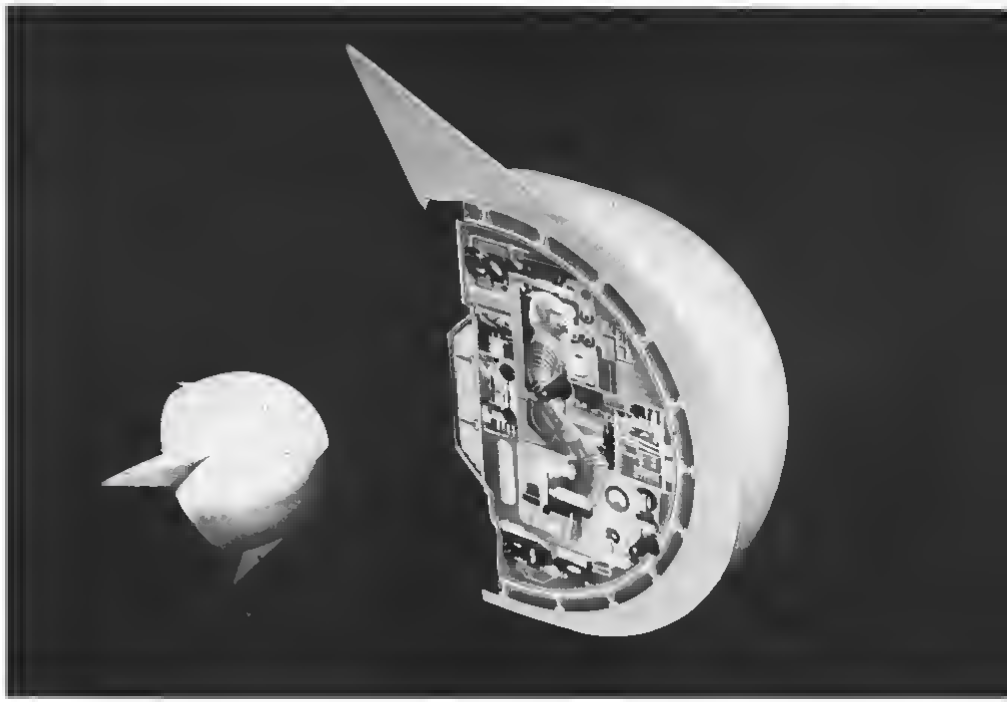
Closer to realization—but still estimated to be approximately five years away from operational capability—are the solid borane rocket fuels under development at Olin Mathieson and Callery Chemical. At present although these companies expect to develop advanced oxidizers to go with the new solid borane fuel, they are still chained to conventional oxidizers such as ammonium perchlorate for the present and as a result are probably not able to attain specific impulses above 300.

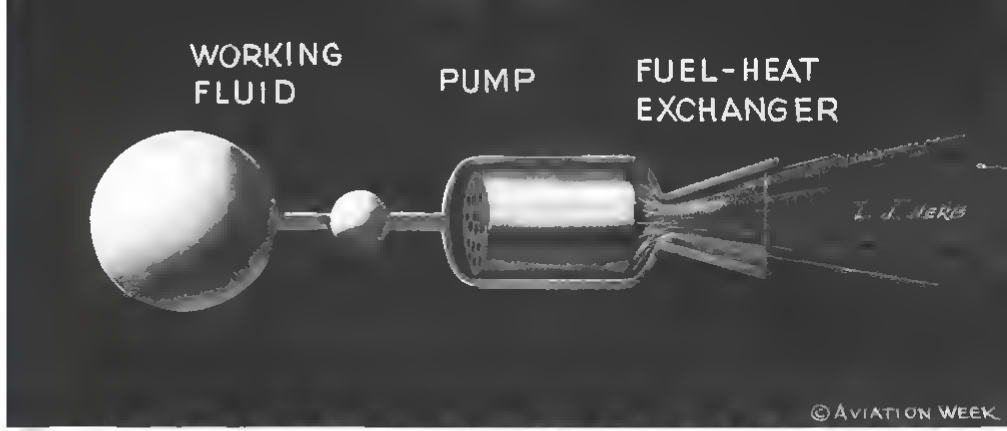
Actually, most of the current research work on high energy solid propellants is concentrated on the achievement of smaller but more immediate energy gains by such means as the addition of powdered metals like aluminum, boron and magnesium to presently available solid propellant mixes. When you start talking about specific impulses above 300, one missile man declares, you're talking about space propellants; there is really little need for them here on earth. ■



Ames Laboratory Proposes Piloted Re-Entry Satellites

National Advisory Committee for Aeronautics' Ames Laboratory delta wing piloted satellite proposal (above) would have blunt nose and blunt swept wing and fin leading edges to reduce aero dynamic heating. It would employ conventional landing techniques. Hemisphere proposal (below) has heat shield of combined radiation and heat sink design. Beryllium oxide outer shell is supported from inner capsule which is heat-shielded by insulation. Seat rotates 180 deg. vertically so pilot can adjust self to resist maximum 8G deceleration forces





NUCLEAR rocket engine will bridge the gap between conventional propulsion systems and the more sophisticated systems of the future.

Advanced Propulsion Research Speeded

The nuclear rocket engine now under development at North American Aviation's Rocketdyne Division is a significant first step into space propulsion, serving to bridge the gap between present and future. Its development is well within current technical capabilities, and, at the same time, it will be the first rocket engine to produce power not based on the conventional chemical oxidation reaction.

Although no details of the first nuclear rocket powerplant have been released, it is generally assumed that it will use a heat exchanger to transfer the heat from uranium fissioning to a working fluid such as lithium hydride or high pressure hydrogen which would then be exhausted at extremely high velocities out of a convergent-divergent nozzle. Direct exhaustion of fission products without going through the heat exchanger working fluid step appears highly unlikely at this time because of the random nature of the particle velocities.

Estimated specific impulses for a fission rocket range from 250 to 2,500. In the first operational fission rockets, specific impulses are not expected to run much higher than those attainable with high energy chemical fuels. The technological problems involved in the development of such a rocket are formidable and it is considered highly unlikely that the first nuclear propelled vehicle will be flying much before five years.

Visualizing how a nuclear rocket might look, R. W. Bussard and R. D. DeLauer (in their book, "Nuclear Rocket Propulsion," soon to be published by McGraw-Hill Publishing Co.) see a vehicle closely akin to a conventional chemical rocket except for the engine section. The dead load carried by the vehicle, they say, may be located at the nose of the rocket, just forward of the propellant tanks to achieve maximum use of the propellant for radiation shielding of the reactor and to obtain maximum geometrical separation of the dead load and reactor. Propellant would be pumped from tank to reactor by turbine-driven centrifugal pumps as in large liquid chemical rockets.

High Weight Penalty

A major drawback to the nuclear rocket is its high weight, according to Bussard and DeLauer. To have high specific impulse and a high thrust-to-weight ratio, it appears necessary to reduce system specific weight by a factor of 100, and the possibilities for achieving this, they believe, are slight. What is really needed, they say, is a conceptually new, lightweight method of producing shaft power or electrical power from fission.

Carrying this idea of bypassing heavy heat machinery somewhat further, Ben Wilkes, Aeronautical Research Administrator, Headquarters USAF, suggests that the nuclear energy can be used to generate other forms of energy such as ions and free radicals or to generate electricity directly for accelerating ions and free radicals without converting the nuclear energy to heat first.

More efficient conversion of fission energy to propulsion is not the only drawback to the fission rocket. To some scientists, a more important factor is the possibility that the fission rocket will be obsolete before it is even operational (AW May 19, p. 50).

How long will we be satisfied, asks Ramo-Wooldridge's Milton U. Clauser, with the development of a fission rocket that will enable us to circle Mars when we will need a fusion rocket to land on the planet and return? Dr. Clauser believes that the answer is "not for long" and that the fusion rocket engine is definitely the powerplant of the future.

If the basic problem of controlling the fusion reaction can be solved, he adds, there seems to be no further fundamental obstacle that would preclude its use for propulsion. In fact, rocket propulsion might be the appropriate first application for the fusion reaction.

The prospects of developing fusion rocket power within the next 10 years appear very bright to a number of scientists. And since this time span is so close to the development period of the fission rocket, they see little point in spending the large amounts of money and time required to perfect the latter. Other equally eminent researchers disagree and declare that the problem of controlling the fusion reaction is extremely difficult and even, perhaps, impossible.

Likely nuclear fuel choice for the fusion engine is deuterium-tritium, because the reaction between these two materials will sustain itself at a comparatively low temperature. Heating these particles to extremely high temperatures (by some practical method yet to be developed) permits their orbital electrons to escape and greatly accelerates the random motion of the resultant

Exotic Fuels for Propulsion

OPTIMUM CONDITIONS

	FUEL	THEORETICAL MAX I_{sp}
NUCLEAR FISSION	Solid Reactor—H	200-3,500
	Gaseous Reactor—H_2	2,500-5,600
	Liquid Reactor—H_2	1,600-2,600
	Controlled Atomic Bomb	Up to 1 x 10⁵
Thermonuclear Fusion D He 3 He₄		6 x 10⁵-3 x 10⁵
Plasma Jet Gun		700-20,500
	Solar—H₂	1 000-1,500
	Electric Arc—H_2	1 500-3,500
	Ions — Ionosphere Ram	Up to ∞
	Ions — Accelerated	40,000-450,000
	Photons	3.057 x 10⁷
FREE RADICALS	O_2 + H	2,225
	H + H	2,740
	H (Alone)	1,360
	.5 Mol H_2 + 1 Mol H	1,100
	4 Mol H_2 + 1 Mol H	600
	4 Mol H_2 + 1 Mol H	540

ions with the result that the fuel is converted into a high speed plasma The accelerated ions, upon colliding fuse In the fusion some mass is converted into energy Because of the high temperatures and pressures involved it is necessary to contain the reaction within magnetic lines of force since there are no known materials that could withstand the conditions

Theoretically fusion will produce specific impulses close to 3 million seconds but very low thrusts To increase the thrust and at the same time get rid of some of the reaction heat Dr Clauser suggests using a lithium coolant which would first circulate around the engine and then would mix with the plasma This would raise the mass (and hence thrust) of the plasma which would then be exhausted through a magnetic nozzle to produce thousands of lb thrust and a specific impulse of over 3 000 sec

Alternate Method

Another way to generate plasmas is with an electric arc This has already been done by a number of groups including Avco, General Electric and Giannini The work to date has been on a small scale and designed primarily for the production of very high temperatures in connection with materials testing programs Although such plasmas theoretically can be used for propulsion they are presently impractical because of the large amounts of electricity required General Electric has filed for patents on this method of propulsion, one General Electric scientist says engineers now have to figure out some way of getting an electrical generating station large enough to supply a city the size of Philadelphia into a space vehicle

The best choice for a future space propulsion system now definitely seems to be one based on nuclear energy—ideally fusion more practically fission But there are a number of other approaches And as one ARDC propellant man puts it we don t dare overlook any bet in this game where the outlook changes almost daily particularly when research—even by the best brains in the business—is so comparatively inexpensive

Here is a brief rundown on some of the other non chemical high specific impulse propulsion systems now getting some attention

• **Ion propulsion.** This system is based upon the acceleration of ions which are then discharged to provide thrust The ions can be obtained quite easily by impinging one of the alkali metals—lithium sodium potassium, rubidium or cesium—on an incandescent tungsten or platinum surface Currently cesium seems to have the edge on the others because of its high density

Compared to fission and fusion, ion propulsion is considered an easier system to control But again extremely high electricity demand is a drawback According to one estimate 20 000 kw are needed to produce an electromagnetic field strong enough to accelerate the ions fast enough to give a 1 lb thrust The way the Air Force s Ben Wilkes figures it depending on the method of conversion 1 kw of electrical energy requires 4 to 10 lb of weight of nuclear powerplant Thus an ion propulsion system would weigh anywhere from 80,000 to 500,000 lb for each lb of thrust desired

• **Free radical propulsion** Free radicals are, in one sense, simply high energy storage batteries They are molecular

fragments formed when enough energy is put into a molecule to rupture one of its bonds. Thus, they possess the original internal energy of the molecule plus the energy required to break the bond.

The rupture energy is released when the radicals recombine into the original molecule.

The problems involved in generating these radicals in useful quantities, capturing and storing them (under ordinary conditions they recombine almost immediately) are still not completely worked out and, according to some scientists, may never be. There is a great deal of interest and work in this field going on both in Russia and in the United States. But except for a monatomic ramjet now under development (this is designed to operate on the free radicals provided by nature in the upper atmosphere [AW Apr. 7, p. 65]) nothing concrete has come of it.

■ **Metastable propulsion.** Somewhat akin to free radicals, metastables are electrically neutral or charged molecules or molecular fragments in an excited state (i.e. where the orbital electrons have moved to a higher energy level). In one experiment, Aerojet General subjected hydrazoic acid (HN_3) to an electrical discharge and then condensed it at 77K. The acid became activated. When heated, the activated acid gave up its acquired energy and returned to normal.

One pioneer in this field, Dr. Fritz Zwicky, says it is possible to achieve specific impulses with metastables three times those currently obtainable. In connection with this, he also suggests that propellant researchers should spend more time considering the cold reactors involved in nuclear fission as opposed to the hot reactors, which are the current focus of attention.

Unlike the hot reactors, the cold reactors do not produce heat directly. Instead, they generate radicals and excited states in very cold gases or liquids being pumped through them. As the fluid with the frozen radicals and metastable states comes from the cold reactor, it makes a very powerful propellant.

The problems of producing, stabilizing and using metastable compounds are much the same as those involved in using free radicals—except they are much bigger.

■ **Solar propulsion.** As proposed, this system comes in various sizes and shapes. Basically, it involves a device that would collect radiation from the sun by means of an optical system and convert this to thermal energy. The device might be a heat exchanger located at the focal point of a large mirror or "solar sail" fabricated perhaps of extremely thin aluminum foil.

A working fluid such as hydrogen would be pumped through the exchanger, pick up heat, and then be exhausted through an expansion nozzle to produce thrust. Thrust output would be low—very low on a weight basis. Heating 1 lb./sec. of hydrogen to 3,600 R, according to one study, would require 16,000 sq. ft. of projected area. At present solar energy doesn't appear very promising for propulsion. At the same time, however, it has already definitely established its value as a secondary power source for operating electronic equipment and the like.

■ **Photon propulsion.** Basis for this system, as envisioned in some proposals, are the quanta of light or electromagnetic energy that would be ejected by some radiating source to produce thrust. The interest in this system stems, of course, from the fact that distances involved in interplanetary travel are so tremendous that they are measured in light years. So in order to do much exploring it will be almost necessary to travel at the speed of light, and the only thing that moves (or can be used to move) at this speed is light itself or electromagnetic radiations.

The trouble is that the radiation surface and power required to eject the necessary amount of photons is near fantastic. One estimate says that a surface 100 x 370 ft. will be needed just to balance a one ton rocket against the gravitational pull of the earth. Another envisions a surface thousands of feet in diameter and operating at billions of watts. In a somewhat different form, it has been calculated that 10 million kilowatt hours would be required to produce a photon thrust of one pound for 7½ hours—provided that 100% efficient conversion could be achieved. And at the present state of development conversion efficiency probably wouldn't run above 3%.

The Outlook

With the possible exception of nuclear rockets, most of these advanced propulsion schemes appear desirable only for service in flight beyond the earth's sensible atmosphere. It is here that their disadvantages of high weight and low thrust will be minimal and that their high specific impulse and low fuel consumption will be in a measure the overriding (and vital) considerations.

Chemical rockets will probably be used as boosters to get space vehicles off the earth. They may even be used as sustainer engines for comparatively short space flights, say, earth to moon and back. But for extended interplanetary travel or exploration, some new means of propulsion will be needed. In all likelihood it (or they) will be based on one or more of the schemes discussed here. ■

SOVIET spacemen focus sun's rays to weld space station section in scene from popular science film.

Foreign

U. S.-Soviet Satellites Compared

PARAMETER	VANGUARD I	EXPLORER III	EXPLORER I	SPUTNIK III	SPUTNIK II	SPUTNIK I
IGY designation	1958 beta	1958 gamma	1958 alpha	1958 delta	1957 beta	1957 alpha
Launching time	7:26 A.M. E.S.T. Mar. 17, 1958	12:38 P.M. E.S.T. Mar. 26, 1958	10:55 P.M. E.S.T. Jan. 31, 1958	May 15, 1958	Nov. 3, 1957	Oct. 4, 1957
Launching place	(Cape Canaveral, Florida)			(Kapustin Yar-NW Caspian Sea Area)		
Orbital period (min.)	135	115.87	114.95	100	103.7	96
Apogee height (statute mi.)	2,513	1,741	1,575	1,178	1,025	560
Perigee height (statute mi.)	408	117	227	155	143	148
Apogee velocity (ft./sec.)	16,208	23,000	22,550	21,458	22,250	23,790
Perigee velocity (ft./sec.)	27,100	23,700	24,300	26,700	26,700	26,100
Initial orbit eccentricity	0.1951	0.1601	0.1387	11	0.0971	0.0487
Semi-major axis (R = earth radius)	1.3468	1.2344R	1.2276R	1.107R	1.147R	1.0844R
Area-mass ratio of satellite (ft.²/lb.)	0.00675	0.06535	0.0637	0.0795		0.01529
Geometry of satellite	sphere d = 6.4 in.	cylinder (d = 6 in. length = 80 in.)	cylinder	cone base is 66 in. height is 11 ft. 9 in.	cone d = 59 in. at base	sphere d = 22.8 in.
Roundness ratio of satellite	1	13.3	12.3	2.98		1
Instrument weight on board (lb.)	3.4	20.13	18.13	2,133	1,110	184
Inclination of launch	34.5°	33.467°	34.5°	65	65	65°
Heading	124.5°	123.487	124.5	25	25	25°
Total weight placed on orbit (lb.)	57.1	32.4	30.8	3,558*	2,880*	330*
Weight of launching vehicle (lb.)	22,600	65,000	65,000	182,000	182,000	182,000
Total thrust (lb.)	27,000	83,000	83,000	264,000	264,000	264,000
Thrust burning time (sec.)	336	160	160	Unknown		239*
Lifetime of satellite	20 R* yr.	72.4* days	1,500* days	930 days	162 days	92 days

* Estimated

Soviet Lead in Space Due to Foresight

Soviet Russia, still pacing man's exploration of space eight months after the launching of Sputnik I, is operating with a tremendous time advantage gained by foresight and careful preparation.

Neither the total effect on the present nor the ultimate outcome of Russia's lead will be clear until long after man himself has followed his automatic sensors into space. Both have been overestimated, re-assessed and underestimated many times since Oct. 4.

What is clear is the broad educational, scientific and technical base underlying the Soviet astronautics program and the national priority supporting its carefully-organized execution.

This program calls for approximately the same steps in about the same order as the programs proposed in the U.S. Judging by recent Russian statements, these developments might be expected in the near future:

- **An attempt to create living matter** inside a Sputnik, using inorganic matter and cosmic radiation. Satellite would contain a mixture of ammonia, methane, steam and carbonic acid to reproduce what scientists believe may have been the composition of the earth's atmosphere at the beginning of life. One Communist source said this experiment would be attempted in Sputnik III, but Soviet announcements since Sputnik III's launching have not confirmed this.
- **Launching of another animal satellite.** A small dog named Alpha is now being given special training, according to Ada Kotovskaya, Soviet woman physicist. Mme. Kotovskaya was quoted as saying before Sputnik III went up that Alpha would be aboard the "next Sputnik." Soviets have not said that Sputnik III carries any living passengers.
- **Recovery of animal passengers.** Mme. Kotovskaya said that new Sputniks capable of bringing back their animal passengers, are being prepared now. Yu. A. Pobedonostsev, member of the Interdepartmental Commission on Interplanetary Communications (travel), was quoted—again, before Sputnik III was launched—as saying that "experimental animals will be recovered from the next artificial satellites. The place of landing will be precalculated. The satellite will be observed and the precise landing spot will be determined."

A possible explanation of the six-month lag between the launching of Sputniks II and III and the reports of trouble in launching attempts might be that animal-bearing satellite launches failed in the interim, and that Sputnik III finally was substituted as the next vehicle. A more probable explanation is that launching vehicles were diverted for the atomic and thermonuclear warhead tests carried out between satellite launchings.

Recovery, however, apparently still has not been solved in the Soviet Union. Academician Leonid Sedov, Chairman of the Interplanetary Commission, pointed out that Sputnik III "could easily carry a man with a stock of food and supplementary equipment." But, he said, "such an experiment would have been premature. Before it is attempted, more knowledge must be gained about the conditions of man's existence in cosmic space, and the basic problem of the return to earth must be solved."

- **Launching of a Communist Chinese satellite.** Kuo Mo-Jo, president of the

Chinese Academy of Sciences, said after Sputnik III was launched that "Chinese scientists are determined to get China's artificial earth satellite into the sky at an early date."

It is not possible from his statement to determine what is meant by an early date. "In order for this to materialize," he said, "we have to expend very great efforts. However, there will be a day when the artificial earth satellite of China will go into the sky. The earlier that day comes the better."

While Russia will continue to exploit every facet of advantage that its pioneering has given it, Russian scientists themselves have discarded most of the anti-western criticism that marked their writings on astronautics a few years ago. They now call for international cooperation of scientists, and suggest that the science of astronautics might provide a bridge across the gap of human misunderstanding.

Neither the elevation of the scientist and technician in Soviet affairs nor the great degree of effort devoted to the Soviet space program is surprising.

Rear Adm. John T. Hayward, Assistant Chief of Naval Operations for research and development, has pointed out that 60% of the members of the National Presidium are graduate engineers.

The USSR Academy of Sciences, a select group of 150 to 200 members with another 300-350 corresponding members, has an important if often indirect voice in the conduct of Soviet technological programs.

Strong Foundation

It is supported by a strong foundation of some 60 institutes, with about 50,000 employes, a number of research stations, laboratories, museums and observatories spread throughout the Soviet Union and increased considerably during the International Geophysical Year, and a broadening scientific base in other Iron Curtain Countries. Red China, for example, has established 1 000 meteorological stations, 20 seismological stations and 12 satellite tracking observatories, most of them in the past few years.

As Gen. James H. Doolittle, chairman of the National Advisory Committee for Aeronautics, pointed out in testimony before the Senate Preparedness Investigating Committee recently, Russia enjoys its lead in long-range missiles and astronautics because "she started sooner . . . she is working harder . . . she is sacrificing more . . . she has a definite, clear-cut objective."

"Their excellent educational system and their appreciation of the value of science are largely responsible for their rate of technological progress," Doolittle said, "and for the fact that in some areas they are ahead of us . . . The real threat is their rate of progress. (It) is much more rapid than our own."

In all branches of space technology, Russian efforts seem to be moving in much the same directions as in the U.S.—but perhaps faster. Open literature discusses all the standard problems, including human factors.

Eleven years ago Russia founded a Department of Astrobotany. She has put great emphasis on boost-glide aircraft, possibly powered by an atomic engine with liquid hydrogen fuel. This engine is believed to be in development now. She has done considerable research on oxygen regeneration for use in manned satellites and submarines, appears to have advanced ramjet technology faster than ours and has extensively explored high temperature metals, free radicals, boron fuels and metal slurries. She has been developing atomic engines for use first in drones and missiles, where shielding problems are greatly reduced and appears to have developed an astronavigation device that determines the distance of a space ship from the sun by means of temperature measurement.

Use for detection, guidance and communication of the powerful, short-lived electromagnetic impulses generated by explosions—a phenomenon now being investigated intensively in this country (AW May 12, p. 26) disappeared from the unclassified Soviet literature in 1954 apparently to go "underground."

Rand Corp. economist Burton Klein has pointed out that Russian progress is due in part to a belief in parallel investigations in research in contrast to U.S. attempts to avoid duplication at all costs.

"Far from decrying duplication, the Russians have organized it and given it the status of a principle in their research and development," Klein said.

Other observers agree, but emphasize that Russia carefully avoids what can clearly be determined to be needless duplication of effort, through better organization of its technical talent. The Soviets also avoid repetition of western investigations whenever it is feasible, partly by keeping abreast of western developments through a vast translating and disseminating organization under the Academy's direction.

Russia apparently used "organized duplication" as its approach to ballistic missiles. Starting largely from German achievements, Russia pushed ahead on a variety of medium and long range missiles even when weight of atomic warheads seemed almost prohibitive. The powerful engines developed originally because they seemed militarily necessary are paying off handsomely both for missiles and for space vehicles.

Students of Soviet capability in the rocket and space field such as F. J. Krieger of the Rand Corp., author of A Casebook on Soviet Astronautics (RM-1760 and RM-1922), credit early Russian rocket enthusiasts with making many original and fundamental contributions to the technology.

As far back as 1929 disciples of the Soviet "father of astronautics" K. E. Tsiolkovsky, founded what Krieger calls a competent scientific organization for

Soviet Space Group

Members of the Interdepartmental Commission on Interplanetary Communications which coordinates Soviet space research are:

L. I. Sedov, chairman, G. I. Petrov, vice-chairman, B. Yu. Levin, M. A. Lavrentev, P. L. Kapitsa, N. N. Bogolyubov, A. A. Blagonravov, A. A. Ambartsumyan, S. A. Lebedev, P. P. Parenago, V. L. Ginzburg, V. A. Trapeznikov, N. V. Petrov, D. N. Frank-Kamenetskii, S. E. Khaikin, G. I. Pokrovskii, A. P. Vinichev, Y. A. Pobedonostsev, G. N. Duboshkin, K. P. Stanyukovich, V. F. Bolkhovitinov, Yu. A. Florov, N. P. Babashev, A. G. Mosevich, A. V. Maikov, D. E. Okhotsimskii, A. G. Karpenko.

investigating and systematically developing new rocket devices." It was called GIRD from the Russian initials for Group for the Study of Reactive Motion."

Some of its founders such as Pobedonostsev are still active in astronautics work.

Stalin, a fan of Tsiolkovskiy's, took a personal interest in Soviet rocketry. In 1934, eight years before the U.S. began a systematic rocket investigation program, the Soviets organized a government sponsored rocket program.

When World War II ended in 1945, Russia "liberated" not only a group of German rocket workers but rocket factories and test stations and a vast amount of detailed material from German industrial firms and scientific and technological institutes," according to Krieger.

Russia itself claims a rocket preeminence going back more than 100 years, and dates its own chronology from the establishment of the Moscow Institute in 1680.

Russian authors such as Col. N. N. Denisov, L. K. Baser and I. A. Merkulov in charge that French, German and U.S. rocket scientists "have knowingly passed over in silence our (Russian) superiority in this field."

On the other hand, some Russian scientists have freely admitted that Russia has borrowed heavily from the West. Academician Alexander N. Nesmeyanov, president of the USSR Academy of Sciences, said recently that when the Soviet Union has been behind the western world in applied science in the past, it has had to stress engineering and technology, and depend on foreign achievements in basic science.

Now the USSR has caught up in applied science, Nesmeyanov said, and it must develop its own basic scientific research more rapidly.

Although the intercontinental missiles and the Sputnik launchers are primarily examples of engineering rather than basic work, they are good examples.

And although they have been achieved with what western engineers call a brute force approach, with little concern for miniaturization and optimization, some observers expect to see an increasing amount of sophistication in Soviet work.

Sputnik III already shows a trend in this direction. In addition to being a true "space laboratory," it includes solar batteries, devices for storing information and transmitting it only over unceiving stations and elaborate temperature regulating and programming devices.

Whether it contains reconnaissance devices is not known. Russia has not announced that it did. But Soviet scientists have never overlooked the importance of reconnaissance as a useful function of satellites.

Some four years ago the Large Soviet Encyclopedia included in a discussion of astronautics the likelihood of using satellites for "photographing of terrestial surfaces in map making," and said automatically controlled rockets would be used for carrying photographic cinematographic, and television equipment.

Beyond the Sputniks

A. A. Shternfeld, a pioneer Russian astronautics enthusiast and laureate of the International Encouragement Prize in Astronautics, has said that if Sputnik III "were replaced by an ordinary one stage rocket of the same weight, fitted with all the necessary scientific equipment and capable of developing a speed of a bare 3.5 kilometers per second it could make a flight to the moon, Mars or Venus."

While Russian moon and planetary probes probably are not far away from launching, they could be proceeded or followed closely by flight of the T-4A hypersonic bomber, a nuclear aircraft or chimpanzee or man carrying Sputniks put into orbit by the 800,000 to 1,000,000 lb. thrust engine reported to have been in development in Russia for some time now. ■

Europe's Space Research Is on Paper

By David A. Anderton

Geneva—European research aimed at space travel is conspicuous by its absence.

There are now no clearly identifiable solid contributions being made to space technology other than paper studies and some cosmic thinking on the part of Europe's scientific community.

This is not to underrate the value of such conceptual exercises, but rather to underline the lack of facilities and funds for carrying them through. Even in the final analysis there is a single reason underlying the lack of tangible space-flight programs here. Money.

The number of hypersonic shock tubes for example, can be counted on the fingers of one hand. There are two small rocket programs with very limited numbers of rounds, contributing to the International Geophysical Year program. There is a single re-entry test vehicle. There is a single ballistic missile program with its future promise of possible space study vehicles just getting under way.

Lack of Money

The reasons for this are plain. In all of Europe, only Britain, France and Germany are in a financial position to make any sort of major contribution to weapons programs. Space flight here as in the United States is inextricably wound up together with long range missile programs.

But Britain is abandoning supersonic aircraft before having fully understood them, and is hopefully pinning its position on missiles which haven't been designed yet but which are expected—as always with any new British weapon—to be far ahead by the time they reach service.

France on the edge of bankruptcy because of its extensive commitments in Algeria has cancelled one aircraft program after the other and is now down to stretched-out production of two or three and weak financing of one or two prototypes. Its missile effort is essentially nil.

German Missiles

Germany recently regaining some measure of authority over its own rearmament by being allowed to develop small missiles again, is still too far from realization of any sophisticated weapons to make specific contributions.

So none of these three is able to divert any effort to space flight. Instead informal study groups, various institutes connected with universities and individuals have been working in their spare time trying to keep alive the traditions of space flight.

For Europe does have these traditions paradoxically, it was the cradle of space flight, born a breezy morning in October 1942, when the first successful German V-2 rocket soared into the sky over Peenemünde. And along before the young and enthusiastic engineering teams under the capable young and enthusiastic Wernher von Braun had seen their ideas grow to realities. European scientists, engineers and technicians were dreaming the dreams and publishing the monographs that were to inspire later generations of doers.

But is with much of modern technology, it took the impetus of war with the amassing of test data on the V-2 to give shape to the theories of Oberth, Tsiolkovskiy and von Pirquet.

The first postwar years produced a few sorts of space-flight reports, but these were different. They had solid numbers based on German experience with the V-2 and other missiles and they all reached essentially the same single conclusion. Space flight was now theoretically practicable.

The only catch was that facilities were needed to translate theory into practice. All the rocket motor data in the world did absolutely no good unless applied to a specific project with the end point of producing a running powerplant. And this was where Europe never had a chance. The scale of postwar rocket development was at a level far below the valleys in Peenemünde's 12 years of cyclic life.

Paper Studies

While the frustrated space flight enthusiasts in Europe watched U.S. engineers plunged headlong into an enormous guided-missile program, involving millions of dollars worth of facilities that would serve to aid the development of the tools of war or the exploration of space. Knowing that their contributions could not match developments in the U.S., Europeans turned back to the paper studies and sketched and calculated paths to the stars.

Perhaps the most notable European contribution to contemporary space flight was a paper on "Minimum Satellite Vehicles," presented by K. W. Gatland, A. M. Kunesch and A. E. Dixon of the British Interplanetary Society at the Second International Congress of Astronautics in London in 1951. The authors believed that nobody had taken a careful look at the problems of launching the minimum useful satellite—most previous authors seemed to be worrying about major payloads of extensive instrumentation or a complete environmental cabin with a man inside.

The British engineers allowed 10 pounds for the final satellite, which was to be an inflated foil sphere blown up by a small gas capsule after separation in orbit, and acting as a radar reflector. A radio beacon and perhaps a single instrument could be included in the payload.

Other Technical Features

There were other technical features of the British proposal that in retrospect were advanced for their day, and which have since been incorporated in both satellite and weapon rockets.

- **Lightweight integral propellant tanks** made of thin walled structure and internally pressurized to carry the load. This technique is now used in the Atlas and Thor missiles.
- **Elimination of the fins** usually incorporated to give static and dynamic aerodynamic stability. This was a characteristic of the Vanguard proposals and test rounds: it had also been suggested by other engineers in missile programs.
- **Gimballed motors** and small gas jets for control after burnout. These are also features of today's weapons and satellite rockets.

But aside from this feasibility study and others like it there has been little else contributed to space flight technology by British engineers and scientists.

The Skylark, a solid propellant rocket developed as part of Britain's many contributions to the IGY, represents a project now capable of adding to the fund of knowledge about the upper atmosphere and the fringes of space. Skylarks fired from the long range missile test ground at Woomera, Australia have reached altitudes approximating 100 mi. well into space environments and have recorded and transmitted important data. But with this program as with other projects in the overall tasks of the IGY it must be realized that the primary purpose is to learn more about the earth and not about space flight.

Thus the contribution of Skylark to the sum total of man's knowledge about space must be considered as a secondary objective of its major job.

But recently a strong call for a British satellite program has come from Prof. A. C. B. Lovell, director of the Jodrell Bank radio astronomy station responsible for much of the precise tracking information gained on the Russian Sputniks. Lovell said: "I feel that we

are likely to be in an extremely undignified position in 10 to 20 years if we have no place in this satellite or space flight program. Are we going to have to buy space from America or Russia in the future, and thus be classed as an under-developed country?"

Small Development Cost

Lovell also pointed out that the rockets developed as weapons could be adapted for satellite work, and estimated the cost of such adapted rounds as only a few million pounds. Presumably Lovell was referring to the British IRBM program now starting under de Havilland Propellers as prime contractor.

Not all of Lovell's professional colleagues seem to share his views. Britain's Astronomer Royal, Prof. Woolley, has gone out of his way on several occasions to declare the Russian satellites a hoax and to express sarcastic comments about the scientific value of such devices, even if they weren't hoaxes. But since the third Russian satellite, following on the heels of three successful American shoots, Prof. Woolley hasn't been heard from.

Now in Britain a group within the British Interplanetary Society, readying to celebrate its 25th anniversary as an organization devoted first and foremost to space flight, is working to create some interest in a British space flight program. "What we hope to do," one of the group told AVIATION WEEK, "is to get people interested and thinking about the problems. That's going to be the hardest job."

Specific Contribution

"We also are studying the entire field looking for some area which has been ignored and where we can make a specific contribution. It will probably be a paper study again, because we don't have facilities or funds. But we hope to be able to make a contribution—we have some good people with good ideas, you know."

No facilities, no funds, but good people with good ideas. This is the status of Europe's position in space technology today. ■

Picture Credits

79, 81, 82, 97—NACA, 83, 85, 93, 94, 167—Mt. Wilson-Palomar Observatories, 105, 131, 197, 199—U.S. Navy, 107, 187, 189, 199—USAF, 137 (top), 175 (top)—Wide World, 137, 139, 141 (top), 243—U.S. Army, 153—Caltech, 175, 268—United Press, 179, 183—Cornell Aeronautical Laboratory.

ARPA May Direct Man-in-Space Project

Los Angeles—Advanced Research Projects Agency may take over USAF's Man-in-Space Soonest project, Rear Adm. John Clark, deputy director of ARPA, told a news conference here during a semiannual meeting of the American Rocket Society.

Clark also said it is possible to put a man in space in two to three years.

However, Clark went on to say that as of this moment there does not exist a definite man in space program per se but much of the work presently being done such as early development work on a million pound thrust rocket engine, development of communications and power supply systems, are definitely parts of the man in space effort although not specifically oriented that way.

His man in space effort visualized an orbit at 125 140 mi. in spherical, once or twice around orbital vehicle, Clark indicated.

Clark also said it is quite possible that early test vehicles for the WS-117L Pied Piper reconnaissance satellite (AW Oct. 14, p. 26) may be fired as early as October of this year.

Concerning military civilian space programs, Clark said that ARPA currently is developing a long term program, and that representatives of NACA, which will be the nucleus of a future civilian space agency, will work with ARPA in outlining these programs and added that ARPA definitely is not about to start any programs which NASA would not want to continue.

ARPA has submitted to guided missile czar William M. Holaday the number of missile boosters it would require for scientific space research programs, and the 'number is staggering' Clark stated. He added that here production of both Jupiter and Thor may have some benefit in making the required number of boosters in IRBM thrust class available sooner since there is dual source production.

Questioned regarding the relative technical merits of U. S. and Russia, Clark indicated that one of the biggest problems which has plagued military people and others is selecting the proper programs in various areas to support. There is so much talent in this nation devoted to these problems and so many different proposals which furnish different approaches to the solution of many problems that a proper choice of what to support and what appears most promising in terms of time and money is difficult to make at present.

There is some truth to the statement that there has been too much conservatism in high presidential advisory circles, Clark said, but added that other factors have had equal influence on the current progress of the United States' space program, including the factor of multiple proposals and approaches.

Asked why there has not been earlier and more comprehensive basic research sponsored by the military some years ago which would have put this nation on a par with the Soviets in satellite progress and other fields, Adm. Clark said that at the time these efforts should have been supported, there were no definitely outlined military requirements, and since there existed no requirements, there was no funding support. He added that when a definite application became required, it was no longer basic research, but applied effort directed toward a specific goal.

The U. S. can catch up with the Soviets within two years, Adm. Clark said, adding that one of the biggest steps in closing the U. S.-USSR gap was a changed state of mind regarding the status of the two nations after Sputnik was launched.

Gen. Anderson Reprimanded

Washington—Lt. Gen. Samuel E. Anderson, head of the Air Research and Development Command, was publicly reprimanded by Air Force Secretary James H. Douglas last week for reporting that Air Force hoped to launch its three lunar probes in August, September and October respectively.

Anderson's remarks at a Milwaukee press conference immediately drew fire from Roy W. Johnson, director of the Defense Department's Advanced Research Projects Agency, who declared that no final decision had been made as to firing schedules and that any and all announcements concerning lunar probes would come from ARPA rather than the individual services.

Johnson's denunciation was followed a day later by a formal statement from Secretary Douglas. Douglas, acting on Defense Department orders, said Gen. Anderson "had no authority whatsoever to discuss dates when such launchings may be attempted and, as no final decision has been made by ARPA, the so-called planning dates quoted by Gen. Anderson should be wholly disregarded."

Johnson, obviously angered by what he considered an infringement on ARPA prerogative, emphasized that "ARPA will decide when these shots will be attempted." The decisions, he said, "will be predicated on the development of the instruments, the hardware and, more importantly, the tracking equipment. The announcement will be made by ARPA."

As reported by Aviation Week (June 2, p. 15), first of the three Air Force lunar probes originally scheduled to be fired on Aug. 16, probably will be delayed. A primary reason for the delay is that the receiving equipment will not be installed by that time, and personnel associated with the project do not expect the first launch to be made until near the end of the year unless authority for an all-out effort is received.

Payload will be approximately 30 lb., and some instrumentation will be carried in addition to the necessary telemetering equipment.

Retiring USAF Colonel Hits President's Aids

Los Angeles—Air Force Col. William O. Davis, whose resignation from service becomes effective this month, blasted scientific advisers to the President here last week as being responsible for the lag in the U. S. space effort. Simultaneously, he announced that he is becoming an official in Turbo Dynamics Corp., of Minden, Nev., where he said he will direct research into the "whole integrated field" of space technology. Davis, assistant to the director of laboratories, Wright Air Development Center, was earlier deputy commander for operations, USAF Office of Scientific Research.

Davis, sharply critical of U. S. progress toward space, blamed conservatism of certain groups dominated by officials of "influential universities" for the lack of speed in overcoming the Soviet lead.

Davis' criticism was underscored by his declaration of how he intends to operate Turbo Dynamics' research effort as differentiated from the present general system in U. S.

As research director for Turbo Dynamics, Davis said he will want five laboratories working in human factors and space medicine—materials including solid state physics and electroradiation characteristics of various metals, electronics, electromagnetics, propulsion, again featuring electromagnetic work rather than conventional chemical or upcoming nuclear systems, systems which essentially is an information exchange in which cross fertilization of the four other fields is accomplished.

The research effort, he said, would involve 75 to 100 persons and be supported by required laboratory facilities but would specialize in thinking rather than doing in evolution of new concepts and approaches. Davis said engineering to assure feasibility would be accomplished if indicated required and/or funded.

He also declared that currently there is no one who has specialized in the whole of space technology, nor he added, is there anyone in the U. S. now charged specifically with producing new concepts or new approaches in space technology.

President of Turbo Dynamics organized last year, is James Hoffman. Company is headquartered in Minden at Douglas Tahoe Airport, around which company hopes to build an industrial park. Hoffman indicated that the company already has income from other sources such as oil and metals supply businesses and has also sold stock to raise approximately $1 million. Firm will use its income from mundane sources to support its research and development efforts according to Davis and Hoffman. First year's expenditures are set at approximately $1 million, with approximately one half to be company funds from its other sources of income plus its capital.

Senate Group Details Space Agency Proposal

Washington—Creation of a seven man policy making board to establish and supervise the National Space Program was recommended last week in a bill approved by the Special Senate Committee on Space and Astronautics.

The bill, approved by a unanimous vote of the committee, also calls for a National Aeronautics and Space Agency to be headed by a director and a deputy director to assume responsibility and direction of all non-military space activities.

The House earlier passed legislation by a unanimous vote that would create a similar agency but one headed by a powerful administrator with complete control over civilian space projects. It also provided for a 17 man board to act in an advisory capacity to the administrator.

Sen. Lyndon Johnson (D-Tex.), committee chairman, said the overall space program is too important to place all authority with a single head.

The bill calls for the board to be established in the executive office of the President. Its members would consist of the secretaries of Defense and State, the chairman of the Atomic Energy Commission, the Space Agency Director and the heads of three other interested government agencies.

Other major differences between the Senate and House versions include:

- Senate bill calls for a Joint Congressional Committee on Aeronautics and Space. The House bill originally contained a similar provision but was deleted on a motion by Rep. John McCormack (D-Mass.), House Space Committee chairman.
- House bill establishes Military and AEC Liaison Committee and Military and AEC Applications Divisions while the Senate version leaves such committees and divisions to the discretion of the Agency Director.

Senate Approves Record CAA Budget

Washington—Senate last week approved a record Fiscal 1959 budget for Civil Aeronautics Administration. The total was $438 million, $91 million over CAA's Fiscal 1958 allocation.

Concurrently, the President requested $66.2 million in additional funds for the following projects:

- New airport for the District of Columbia, $53.5 million. With the $12.5 million appropriated for Fiscal 1958 land acquisition is under way and a contract for detailed engineering plans and specifications has been negotiated.
- Operation and regulation, $12.7 million. This is for recruitment and training of traffic controllers, maintenance technicians and other personnel to assure that newly installed air traffic control and navigation facilities will be placed in service as soon as possible.

Senate also approved these Fiscal 1959 appropriations:

- Civil Aeronautics Board, $6.1 million. This is $610,600 more than CAB's Fiscal 1958 allocation.
- Airlines subsidies, $40.7 million—$3.5 million more than for Fiscal 1958.
- Airways Modernization Board, $34.3 million. This is the amount requested and $4.3 million more than approved by the House.

X-15 Rocket Engine Test Stand

Looking somewhat like a primitive steam engine, the unit above is in reality Reactium Motors' recently completed static 100 000 lb. thrust test stand for the rocket engine of the X-15 research aircraft. The tall cylindrical object that appears to be a smokestack rising out of the roof of the small building is actually a 150,000-gal. water tank located across the street. The sloping cylinder, at left, is one of two propellant tanks which are an integral part of the stand. The engines are mounted on dollies and readied for tests in another building and are then rolled into the test stand and locked in position. The dollies are designed to hold the engines in various positions besides horizontal for test runs.

Nuclear Rocket Faces Problems

Los Angeles—Advantages of the nuclear rocket are overestimated by many people in the industry and development difficulties are underestimated, a luncheon of the semiannual meeting of the American Rocket Society was told here by Norris E Bradbury, director of Los Alamos Scientific Laboratory. He said the nuclear rocket project is expensive but predicted it will yield a successful propulsion system and superior reactors.

Bradbury said many otherwise well informed people have been led to believe that the nuclear rocket's advantage over conventional rockets in specific impulse would be nearly as great as the advantage of nuclear explosives over conventional ones. Thus would give specific impulses on the order of 30 or 35 million. Actually, he said, improvement over conventional propellants would be by a factor of from two to four, giving specific impulses of 1,000 to 1,500 lb./lb./sec. at best.

Potential improvement by a factor of about 130,000 would require the direct use of the energy released by fission and no means of doing this is in sight. Direct use might be possible if there were a gaseous fissionable fuel which could offer both energy and propellant mass. Since fission is a random process control of the reaction might be impossible in a high velocity stream of fuel. Bradbury reported that with the brief time constants necessary in a rocket, control is difficult even using current solid fuel reactors.

Bradbury said a flightless nuclear rocket called "Kiwi A" will be fired at Los Alamos in the latter part of this year. A later static test nuclear rocket called "Dumbo" now is being designed. Bradbury's group will pass propellant gas through the reactor of Kiwi A at increasing temperatures and will study the operation of the rocket with slow reactor warm up, low thrust and long duration. Bradbury concedes that these conditions are unrealistic from the standpoint of operational rockets but says they are necessary in this early stage of development to analyze starting problems and problems of reactor and thrust chamber design.

Rocket requirement for quick start, high thrust and relatively brief duration are major roadblocks in development program. Necessity of getting reactor up to power with minimum expenditure of propellant gas before lift off and dependence on some sort of heat exchanger to impart energy to the propellant steam means that the reactor and exchanger will be subjected to very great thermal shocks.

High thrust and brief duration will produce inefficient use of fissionable fuel with much left unused at burnout. Bradbury called reactor control for a nuclear rocket a "virtually insoluable problem" because of quick response to variations in power level needed to maintain programmed thrust. He pointed out that in current nuclear power systems, there are 5 or 10 min. in which to make slow, careful adjustment of control rod positions whereas in rockets, there will be seconds or less.

Bradbury said the picture is not as dark as these obstacles make it seem. He said that a relatively modest improvement in specific impulse can make a very significant improvement in payload or range. The nuclear rocket is free to use propellants without regard to combustion problems and could seek the lowest molecular weight to get the best specific impulse. Thus and the weight of the big reactor dictate that nuclear propulsion will be useful only in very large, high performance rockets. High cost due to large investment in fissionable material for use in an inefficient reactor and high development costs created by difficulty of handling radioactive materials during development work have the same effect.

Kunzig Reprimanded By CAB Members

Washington—Statements in a telephone call from Robert L. Kunzig, executive assistant to the chairman of the Civil Aeronautics Board, to Robert M. Ruddick, vice president of United Air Lines, resulted in a denunciation of Kunzig's action last week by Board members and a request for his immediate resignation by member Louis J. Hector.

In a 750 word telegram to the Board, United President W. A. Patterson said Ruddick complained that Kunzig told him CAB members were highly disturbed over the United president's testimony before the Senate Aviation Subcommittee and that "retaliation" could be expected. Questioned by Ruddick about the word, Kunzig said he meant "repercussions."

Kunzig also told Ruddick, according to the telegram, he had received several telephone calls from members of the Senate committee objecting to Patterson's testimony, but he did not identify the callers when he was questioned by Ruddick.

Patterson observed in the telegram that "honest men should not be subjected to retaliation for an expression of honest opinions." He informed the Board members that he thought it was his duty to the company and its stockholders to assure them that there would be no retaliation.

Patterson earlier told a Senate Aviation Subcommittee that CAB findings in the 1957 collision of a Trans World Airlines 1049G Constellation and a United Air Lines DC-7 over Grand Canyon were "an insult to our intelligence" and "one my grandchildren could have written."

Patterson's telegram was answered by Board Chairman James Durfee who said the call was made without the knowledge or authority of any members of the Board and did not reflect its views, Durfee added:

"Never to my knowledge has the Board ever given any intimation of retaliation or repercussions over anything that you or anyone else has said about the Board, whether critical of us or not. Nor has the Board ever been actuated by any such consideration in its deliberations or decisions."

Member Harmar D. Denny in a separate reply assured Patterson that Kunzig's call was unauthorized and that his "unpardonable remarks" were considered "inexcusable."

Hector said he regarded the Kunzig call as an attempt by a government official to "browbeat" a private citizen.

Hector added that he repudiated the action in its entirety.

"To my mind there is only one way to repudiate an action of such serious import," Hector said.

However, Durfee said that he will oppose the Hector motion to replace Kunzig.

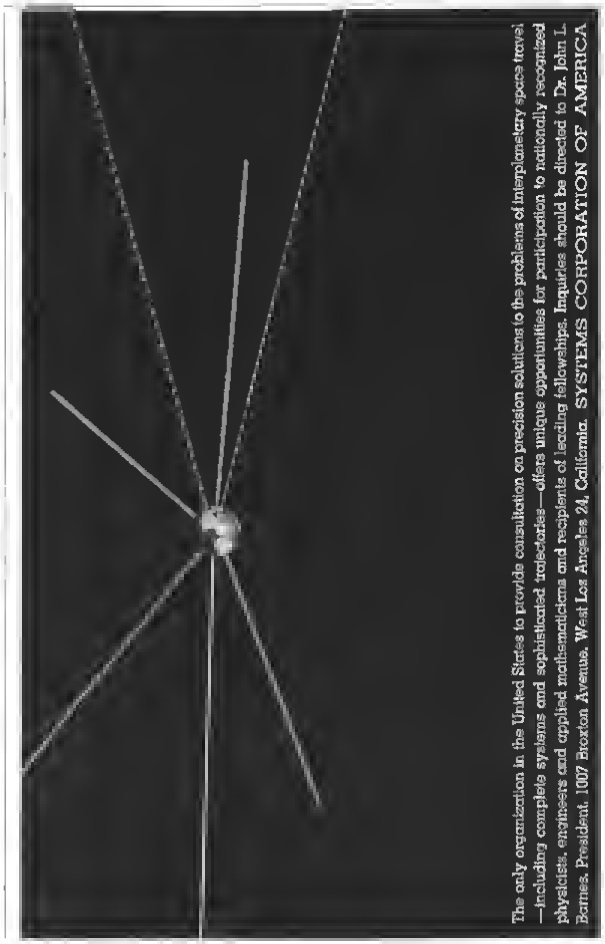
On the basis of his personal study of the evidence at hand, Durfee said that there appears to be a "considerable misunderstanding." He added that in the more than two years that Kunzig has served as his assistant, he had never found an occasion in which Kunzig's actions were not "honestly motivated with both the best interests of the Board and the public interest in mind."

Senate Restores Cuts In Agency Budgets

Washington—Cuts made by the House in National Science Foundation Fiscal 1959 budget requests and all but $380,000 requested by the National Advisory Committee for Aeronautics were restored by the Senate last week.

Conference committees have been appointed in both Houses to iron out differences in the appropriations.

The Senate voted to restore $5,220,000 cut by the House from NACA's budget, bringing the Fiscal 1959 total



to $106,320,000–$9,600,000 below the fiscal 1958 appropriations

A total of $140 million was asked by the National Science Foundation, an increase of $90 250,000 over Fiscal 1958 appropriations The House cut $25 million, all of which was restored by the Senate

In addition, a supplemental appropriation of $7 350,000 has been requested, of which $4 4 million is for salaries and expenses, $2 950 000 for International Geophysical Year projects.

This is how the House and Senate NACA budget versions differ

• Salaries and expenses—Amount requested was $80,480,000 House reduced this by $2,380,000, the Senate restored $2 million

• Construction and equipment—The amount requested was $26 220,000 House cut $3,220,000 all of which was restored by the Senate

The 1959 budget request of NACA does not take into consideration huge increases in expenditures necessary for space activities if the agency becomes the nucleus of the new National Aeronautics and Space Administration, a matter now pending before Congress

Funds for space exploration are contained in the Defense Department budget which would be transferred to the space agency after its approval

ATA Advises Against Fluorescent Paint Plan

Washington—Civil Aeronautics Administration program to mark its fleet of aircraft with daylight fluorescent paint for anticollision purposes has failed to draw the support of the scheduled airlines

CAA's decision to paint its 92 aircraft with the "light reflecting" paint was the result of a successful experiment with a DC-3 which demonstrated that the aircraft was more easily seen under most light conditions when marked with the paint

Air Transport Assn., however has recommended against immediate adoption of the paint by the scheduled airlines on the grounds that the CAA findings are inconclusive regarding the effectiveness and the durability of this type paint

At least four airlines and one helicopter operator are conducting evaluation tests with special high conspicuity paint

Approximately 15% to 20% of each CAA airplane is to be covered with the "blaze" orange fluorescent paint manufactured by Switzer Brothers under the trade name of "Day Glo"

Application of the paint and the marking designs used by the CAA have been approved by the Air Coordinating Committee

ATA has taken the stand that the CAA project still is in the experimental stage The group admits that there are some indications that an aircraft painted with the fluorescent paint would be more visible under some conditions of flight but points out that CAA has found that at greater distances colors lose their identity and aluminum fuselages are more easily spotted

Present plan of the ATA is to make recommendations only after airlines using the paint report their findings and further data is provided by the CAA and military services

Canadians Purchase Runway Arrester

Emergency overrun safety arrester system, developed by All American Engineering Co., has been ordered by the Royal Canadian Air Force for installation at seven airports throughout Canada

Contract for 13 barrier systems came after testing of the device at Uplands Airbase Ottawa Ontario, by the Air Worthiness Section of RCAF's Central Experimental and Proving Establishment

Test aircraft, which included the 34 000 lb. CF-100, successfully engaged the barrier at speeds of 150 mph Safety arrester is said to be capable of stopping aircraft traveling at 160 kt

Installation of two systems will be completed by late summer at Bagotville, Quebec, Cold Lake, Alberta, Comox, British Columbia, Chatham, New Brunswick, North Bay, Ontario and Uplands, Ontario

Overrun safety barrier system adopted combines the MA-1A barrier and Model 340 "water squeezer" arresting engine developed by All American

Swiss Military Head Attacks P. 16 Design

Geneva—Swiss Military Minister Paul Chaudet has charged that Flug & Fahrzeugwerke Altenrhein (FFA) did not follow carefully design requirements for the P-16 ground-attack airplane

An order for 100 production P-16s was cancelled in a decision taken early this month by the seven-man Federal Council, less than three months after the order was placed by majority vote in the Swiss parliament (AW March 24, p. 65) Third prototype P-16 crashed recently in the Lake of Constance, and the accident investigating team has placed the primary blame on the plane's hydraulic power control system (AW June 9, p. 25)

An FFA spokesman told AVIATION WEEK the company was prepared to answer each charge raised by the minister, but thought it proper to wait until the final report was presented at the end of the month

Chaudet indicated that certain structural requirements, based on British criteria which the Swiss have accepted as guiding principles for aircraft design, were not met by the company.

Further, he charged the company had not notified military technicians of important changes in the design as required by contract

Meantime, American and other sales teams have begun again to besiege Bern, the Swiss capital and headquarters of the military and technical groups concerned with procurement It appears that the question of what the Swiss will buy is again an open one, with rumors last week favoring the purchase of perhaps another 50 Hawker Hunters This may be one way for the Swiss to regain the money already paid Armstrong Siddeley Motors Ltd. for license production of the P-16's Sapphire turbojet engine Hawker is another member of the Hawker-Siddeley Group, and only a paper transaction would be needed to keep the money inside the group

Most Swiss opinion still favors license production of an airplane in the country, and the military pilots still have high interest in several non-Swiss types including the Grumman F11F-1F Super Tiger, and the Saab Draken

News Digest

Lewis L. Strauss, chairman of the Atomic Energy Commission for the past five years, will retire at the end of his present term on June 30. In a letter to President Eisenhower, the controversial AEC chairman said he believed a change in the chairmanship advisable because of "circumstances beyond the control of either of us." Strauss will be succeeded on the commission by John A. McCone, West Coast business man and former Undersecretary of the Air Force. McCone probably also will take over the chairmanship after his confirmation as a commission member by the Senate.

Grumman Aircraft and Mitsubishi Heavy Industries have agreed on a program for producing 300 F11F-1F Super Tiger fighters for Japan's Air Self Defense Force. The Japanese company will act as prime contractor of nearly all 300 aircraft. Grumman will produce a small part of the total, with delivery of the 300th aircraft scheduled for 1964.

Lockheed will produce recoverable Mach 2 target drones for the Army under $7.5 million contract. Formerly designated Q-5, Kingfisher is the drone version of the X-7 ramjet test vehicle (AW Mar. 3, p. 329).

Ryan Aeronautical Co., San Diego, Calif. reported earnings of $853,299 for six month period ending April 30, 1958, an increase over $573,634 earned during a similar period in Fiscal 1957. Per share earnings were $1.90, compared with $1.28 last year, and net sales and other income totaled $35,374,896, as against $30,069,769 for the same period last year.

Royal Canadian Navy McDonnell F2H fighters will be fitted with Side winder missiles. Sidewinders, purchased from the U.S. Navy, are now flying with RCN experimental squadron and will be given to operational squadrons as soon as aircraft modifications are made.

ASW Electra Dimensions

Lockheed's Electra anti-submarine warfare version, designated P3V-1 for the Navy, will have the same dimensions as the Electra transport, but will have a 125,500 lb. design takeoff and maximum landing weight. Normal landing weight will be 69,000 lb. Wing loading at 105,500 lb. will be 77.5 lb./sq. ft. Power loading at this weight will be 6.2 lb./eshp.

(Additional employment opportunities con't on page 305)

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